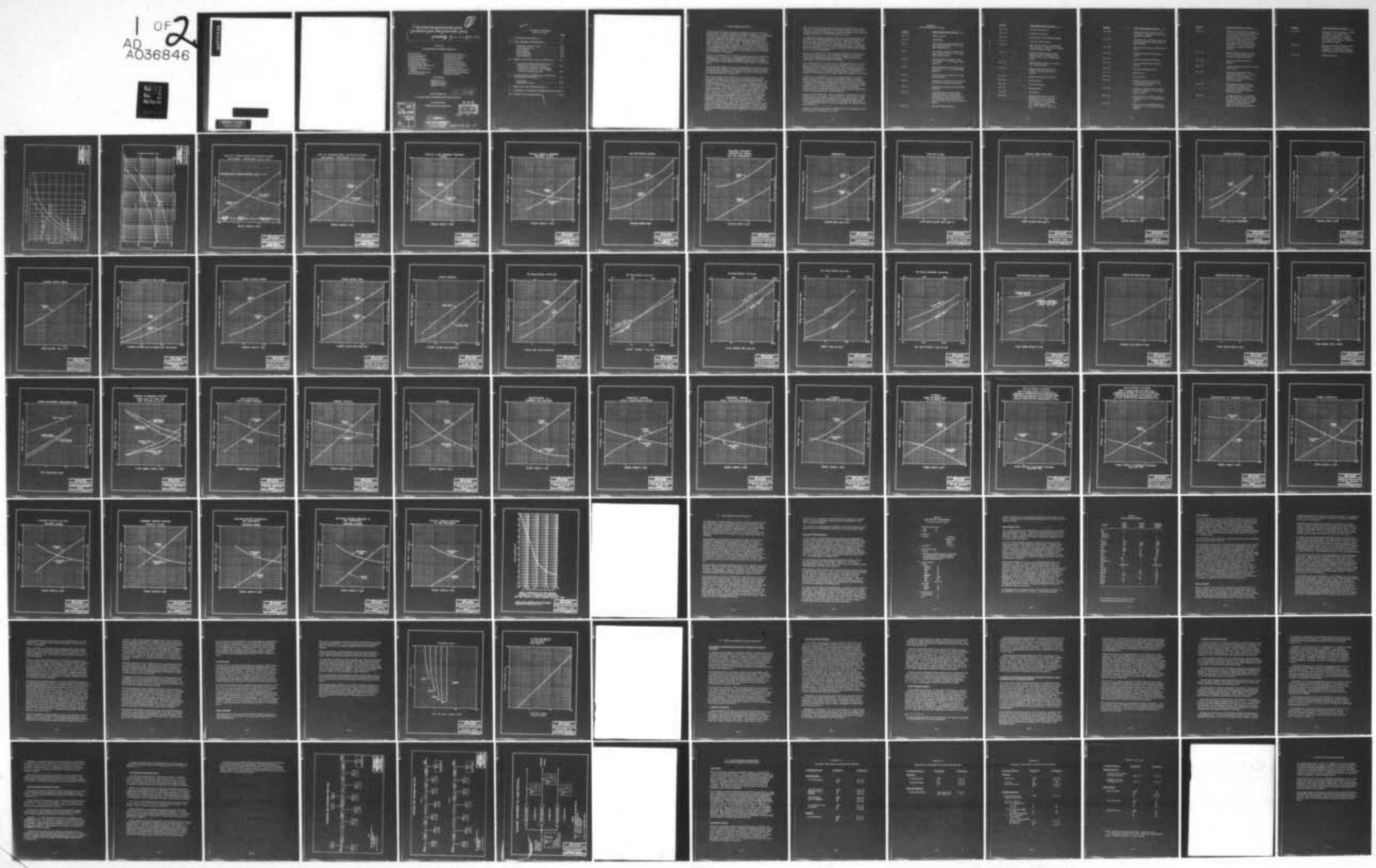
AD-A036 846 ARMY ENGINEER DISTRICT FORT WORTH TEX F/G 13/2

WASTEWATER MANAGEMENT PLAN. COLORADO RIVER AND TRIBUTARIES, TEX--ETC(U)

SEP 73

UNCLASSIFIED NL

1 OF 2
AD
A036846



2

846

1

6 WASTEWATER MANAGEMENT PLAN.

COLORADO RIVER AND TRIBUTARIES, TEXAS.

VOLUME III. Technical Appendix.

Prepared by

THE GOVERNOR'S PLANNING COMMITTEE

Office of the Governor
Texas Water Development Board
Texas Water Quality Board
Texas Water Rights Commission
Texas Parks and Wildlife Department
Railroad Commission of Texas
Texas State Department of Health
Texas State Soil and Water Conservation Board
U. S. Department of the Interior
U. S. Department of Housing and Urban Development
U. S. Environmental Protection Agency
Farmers Home Administration

Lower Colorado River Authority
Colorado River Municipal Water District
Central Colorado River Authority
Upper Colorado River Authority
Capital Area Planning Council
Alamo Area Council of Governments
Central Texas Council of Governments
Concho Valley Council of Governments
Houston-Galveston Area Council
Permian Basin Regional Planning Commission
South Plains Association of Governments
West Central Texas Council of Governments
Nine General Public Members

Honorary Members

Congressman J. J. Pickle
Congressman John Young
Congressman Omar Burleson
Congressman O. C. Fisher

12 150p.

Study Management By

U. S. ARMY CORPS OF ENGINEERS, FORT WORTH DISTRICT

Consulting Engineers

TURNER, COLLIE & BRADEN, INC.

11 Sep[redacted]73

401219 Jmc

content:

TECHNICAL APPENDIX
Table of Contents

I. COST ESTIMATION DATA

This section of the report presents a collection of curves used in estimating costs of collection systems and treatment facilities. In developing the cost curves, data were gathered from both current literature and recent bid tabulations for similar construction. All costs were then adjusted by either the WQO-STP index or the ENR construction cost index to March 1972 for Dallas, Texas. The WQO-STP index used was 144.37 and the ENR index was 1343.41. All construction costs shown do not include engineering, contingencies, land, etc. A separate curve is also presented for each process or unit to show the cost of operation and maintenance either in the form of a total annual cost or a treatment cost in cents per 1,000 gallons.

The first curve (Plate TA-1-1) shows the estimated cost of constructing sanitary sewers. Data used in compiling these curves were recent bid tabulations from the Austin and Highland Lakes areas, and reports covering several of the regional council areas within the Colorado River Basin.

The second curve (Plate TA-2-2) for estimating the costs of lift stations was derived from reports covering the area of study, recent literature, and recent bid tabulations from a number of such facilities constructed in Texas within the past several years.

Next, there are two curves (Plate TA-3-3 and Plate TA-4-4) which present the estimated costs of conventional activated sludge plants ranging in size from design capacities of 10,000 gallons per day to 100 million gallons per day. Cost data for the plants ranging in size from 10,000 to 300,000 gallons per day were furnished by ENVIROQUIP INC. of Austin, Texas. For plants in the 300,000 to 1 million gallon-per-day range, bid tabulations for plants constructed in Texas within the past several years were used. Cost estimates for plants ranging in size from 1 million to 100 million gallons-per-day capacity were derived from "Estimating Cost and Manpower Requirements for Conventional Wastewater Treatment Facilities" by Black and Veatch Consulting Engineers for the U.S. Environmental Protection Agency, Report No. 17090 DAN, October 1971. Two curves (Plate TA-5-5 and Plate TA-6-6) are then presented which show the estimated cost of secondary treatment facilities for trickling filter plants and for secondary treatment by the physical-chemical process assuming lime as the coagulant. These curves were derived from the component cost curves presented herein.

The Black and Veatch Report was also used in preparing the 21 curves (Plate TA-1-7 through Plate TA-1-27) giving estimated costs of various separate components of conventional secondary treatment plants generally ranging in size from 1 to 100 million gallons per day.

Following the component curves are two sets of curves (Plate TA-1-28 and Plate TA-1-29) for estimating the cost of wastewater stabilization ponds by surface area from 1 to 1,000 acres. The first set (Plate TA-1-28) is for non-aerated ponds which generally are 3 to 5 feet deep. The second set (Plate TA-1-29) is for aerated wastewater stabilization ponds, one showing the cost of ponds 10 feet deep, and the other showing the cost of 15-foot-deep ponds.

Next is a curve (Plate TA-1-30) showing the estimated cost of aeration of secondary effluent from 1 mg/l dissolved oxygen concentration to 4 and 6 mg/l dissolved oxygen concentration. This process would generally be considered as tertiary treatment.

The following set of curves (Plate TA-1-31 through Plate TA-1-47) presents cost estimates of several processes believed to reflect current thinking in the area of tertiary treatment. These were derived for the most part from "Cost Performance Estimates for Tertiary Wastewater Treatment Processes," by Robert Smith and Walter F. McMichael, Robert A. Taft Water Research Center, Report No. TWRC-9, June 1969.

The process and component cost curves presented above were used to prepare the set of curves for various treatment schemes considered under the highest level of treatment alternatives as defined in Section 3, "A Rationale for Selection of Wastewater Treatment Processes To Meet A Highest Level of Treatment Objective," for the six metropolitan areas within the Colorado River Basin, including activated sludge units, trickling filters, and physical-chemical processes, along with the other tertiary treatment processes considered herein.

Finally, a curve (Plate TA-1-48) is presented for the estimated cost of engineering as a percentage of construction cost. This curve was used throughout the report for all collection and treatment facilities. A constant 10 percent figure was also used in conjunction with engineering costs throughout the report for the cost of contingencies, interest during construction, etc.

A table of contents listing each cost estimation curve is presented on the following page preceding the cost curves.

TABLE I-1
COST ESTIMATION CURVES

PLATE	COST ESTIMATION CURVES
TA-1-1	Sanitary Sewers
TA-1-2	Lift Stations
TA-1-3	Conventional Activated Sludge Secondary Treatment Plants - 0.01 to 10 mgd design capacity
TA-1-4	Conventional Activated Sludge Secondary Treatment Plants - 0.1 to 100 mgd design capacity
TA-1-5	Trickling Filter Secondary Treatment Plants - 0.1 to 100 mgd design capacity.
TA-1-6	Physical/Chemical Secondary Treatment Plants - 0.1 to 100 mgd design Capacity
TA-1-7	Raw Wastewater Pumping-at sewage treatment plant
TA-1-8	Preliminary Treatment-grit removal, screening, and flow measurement
TA-1-9	Sedimentation-primary and secondary clarifiers
TA-1-10	Trickling Filters-volume requirements assumed to be divided into two filters for total requirements up to 600,000 cubic feet and three or more filters for large-volume requirements.
TA-1-11	Aeration Basin Structures

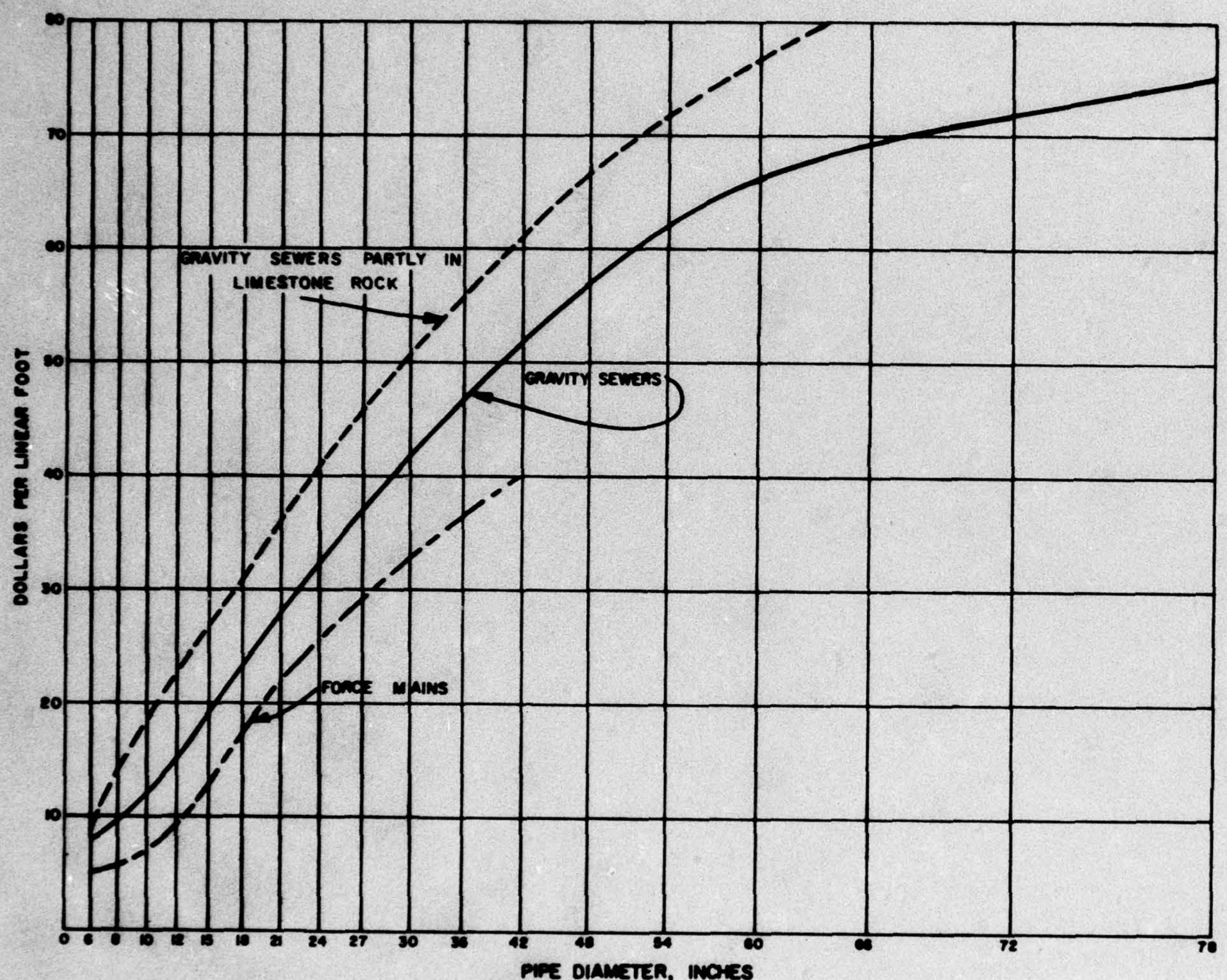
PLATE	COST ESTIMATION CURVES
TA-1-12	Aeration-diffused air
TA-1-13	Aeration-mechanical
TA-1-14	Recirculation-intermediate pumping
TA-1-15	Chlorine Contact Basins
TA-1-16	Chlorine Feed Systems-chlorination feed equipment, chlorine feed building, chlorine storage building
TA-1-17	Primary Sludge Pumping-sludge pumping station consisting of three pumps at each of two sedimentation basins
TA-1-18	Sludge Holding Tanks-prior to filtration or final disposal
TA-1-19	Sludge Digestion-anaerobic or aerobic structures with control building
TA-1-20	Sludge Drying Beds-uncovered
TA-1-21	Sludge Lagoons
TA-1-22	Vacuum Filtration
TA-1-23	Centrifugation
TA-1-24	Incineration
TA-1-25	Administration and Laboratory Facilities-space for personnel supervision, records keeping, correspondence, reception area, well-equipped laboratory, rest rooms, shower, and locker area

PLATE	COST ESTIMATION CURVES
TA-1-26	Garage and Shop Facilities-cost of structures, equipment and tools, and appurtenant facilities
TA-1-27	Administration and General Operation and Maintenance-includes garage and shop facilities
TA-1-28	Non-Aerated Wastewater Stabilization Ponds
TA-1-29	Aerated Wastewater Stabilization Ponds
TA-1-30	Aeration of Secondary Effluent
TA-1-31	Lime Clarification-two clarifier process
TA-1-32	Ammonia Stripping Towers
TA-1-33	Nitrification
TA-1-34	Dentrification
TA-1-35	Phosphorus Removal-alum and polyelectrolyte addition, 0.01 to 10 mgd design capacity
TA-1-36	Phosphorus Removal-alum and polyelectrolyte addition, 0.1 to 10 mgd design capacity
TA-1-37	Filtration-sand or graded media at 4 gpm/sq. ft., 0.01 to 10 mgd design capacity
TA-1-38	Filtration-sand or graded media at 4 gpm/sq. ft., 0.1 to 100 mgd design capacity

PLATE	COST ESTIMATION CURVES
TA-1-39	Partial Filtration-blending of part of secondary effluent having BOD/TSS concentrations of 20/20 mg/l with filtered portion of secondary effluent having BOD/TSS concentrations of 8/4 mg/l to obtain final effluent having BOD/TSS concentrations of 12/9 mg/l, 0.01 to 10 mgd design capacity of secondary treatment facilities
TA-1-40	Partial Filtration-same as above, 0.1 to 100 mgd design capacity of secondary treatment facilities
TA-1-41	Microscreening of Secondary Effluent
TA-1-42	Carbon Adsorption-granular activated carbon filters
TA-1-43	Upgrading Existing Facilities-Activated Sludge Plants - includes nitrification, dentrification, phosphorus removal, filtration, carbon adsorption
TA-1-44	Upgrading Existing Facilities-Trickling Filter Plants-includes nitrification, dentrification, phosphorus removal, filtration, carbon adsorption
TA-1-45	Biological Process Treatment of Raw Wastewater-Activated Sludge-includes activated sludge secondary treatment, nitrification, dentrification, phosphorus removal, filtration, and carbon adsorption

PLATE	COST ESTIMATION CURVES
TA-1-46	Biological Process Treatment of Raw Wastewater - Trickling Filters - includes trickling filter secondary treatment, nitrification, dentrification, phosphorus removal, filtration, and carbon adsorption
TA-1-47	Physical/Chemical Treatment of Raw Wastewater - includes high lime treatment, neutralization, filtration, dentrification, and carbon adsorption
TA-1-48	Engineering Costs

COST OF SANITARY SEWERS AND APPURTENANCES



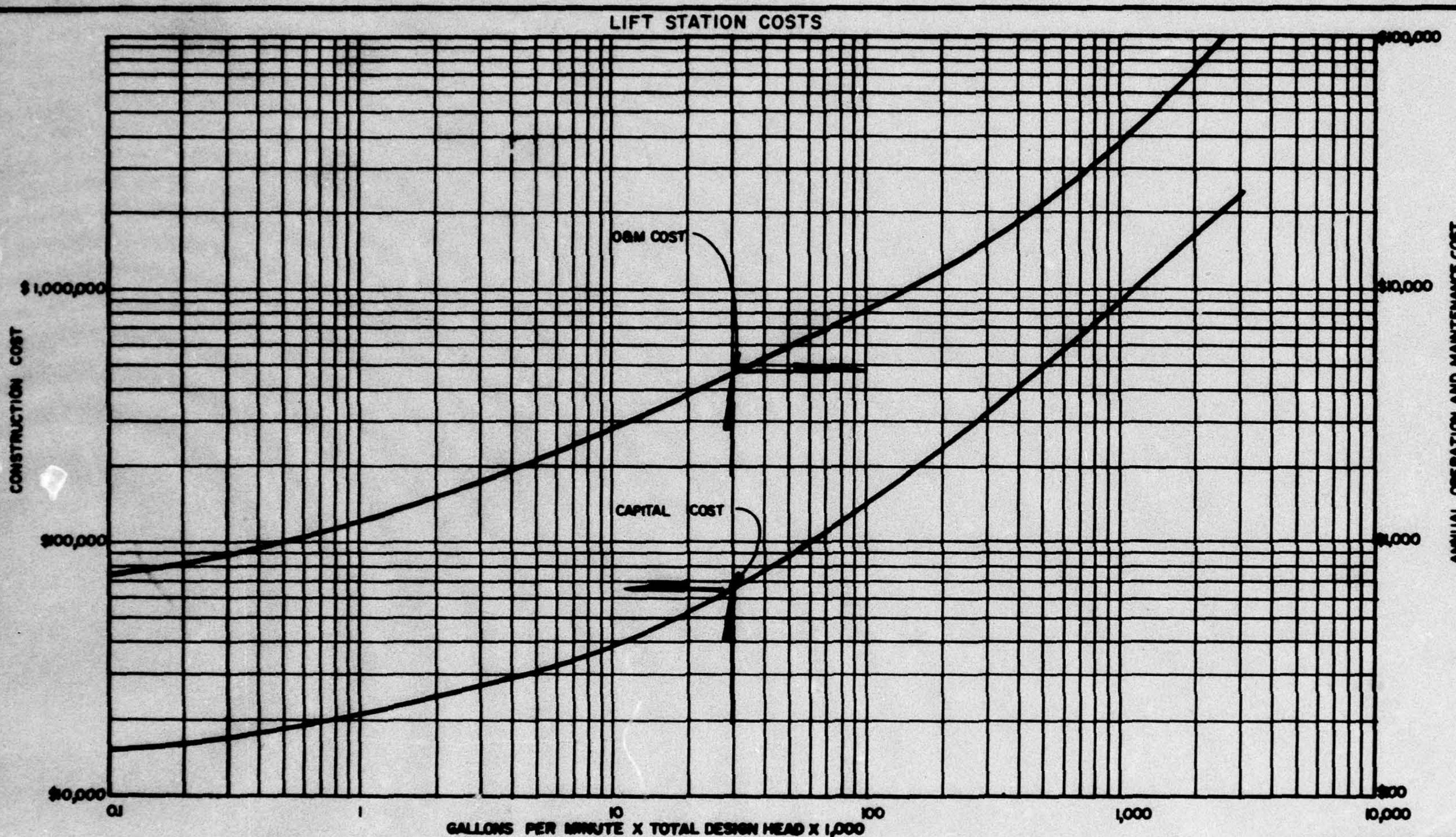
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

COST OF SANITARY SEWERS
AND APPURTENANCES

TURNER, COLLIE & BRADEN, INC. - HOUSTON/PORT ARTHUR

PLATE TA - I - I



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

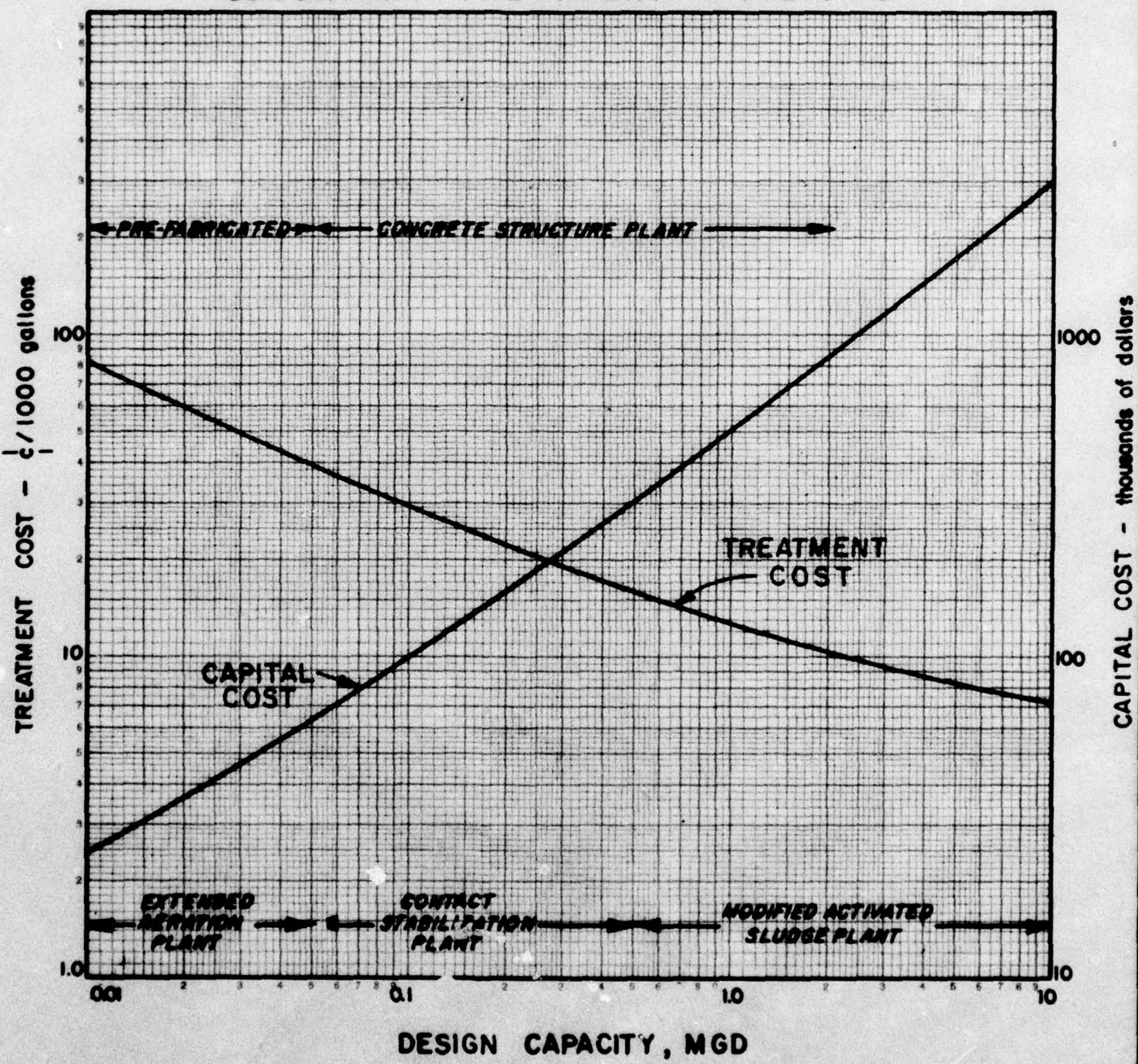
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

LIFT STATION COSTS

TURNER, COLLIE & BRADEN, INC. - HOUSTON/FORT ARTHUR

PLATE TA-1-2

COST OF CONVENTIONAL ACTIVATED SLUDGE SECONDARY TREATMENT FACILITIES



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

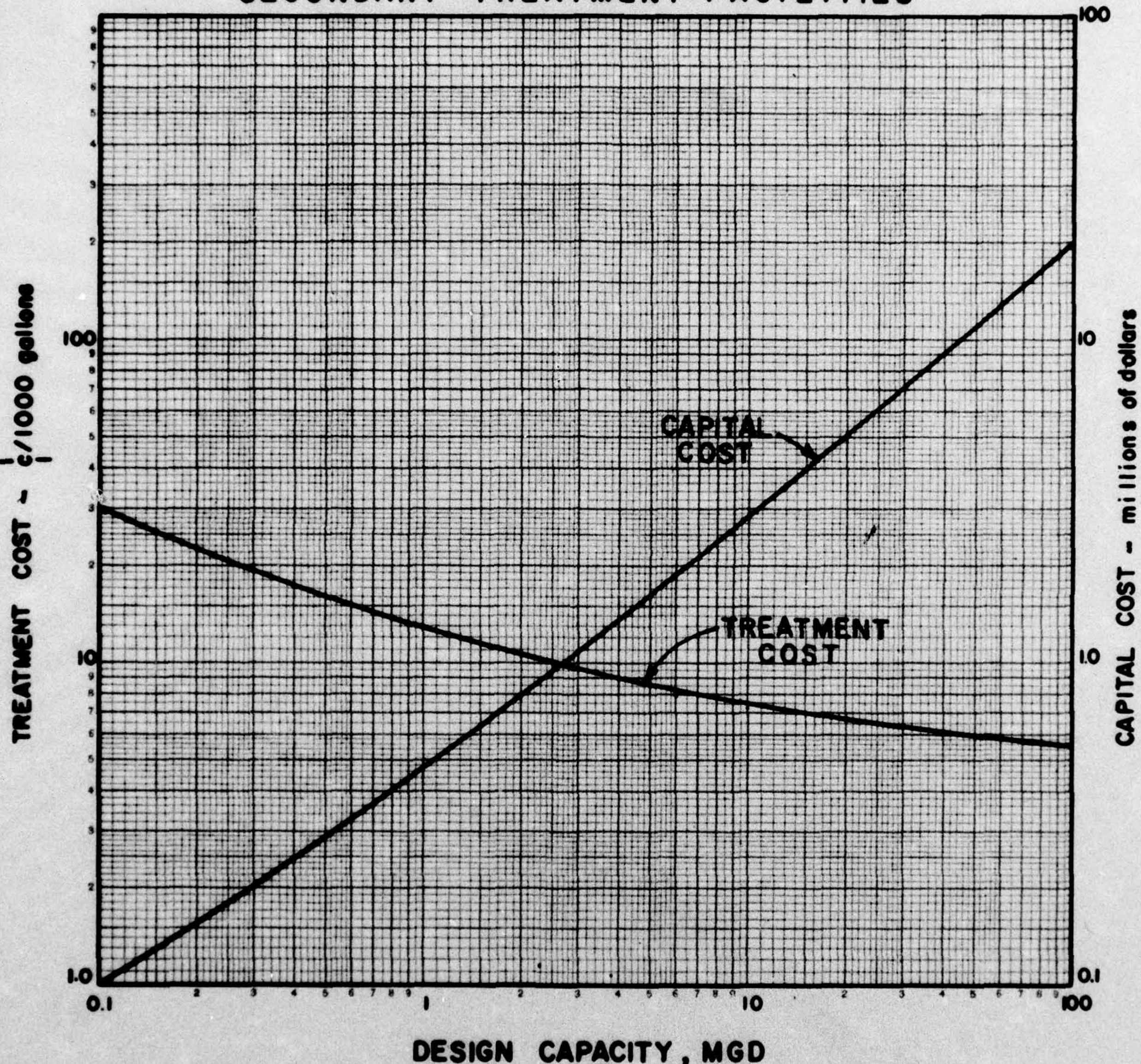
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

COST OF CONVENTIONAL ACTIVATED SLUDGE SECONDARY TREATMENT FACILITIES

[illegible], COLLIE & [illegible], INC. [illegible]

PLATE: TA-1-[illegible]

COST OF CONVENTIONAL ACTIVATED SLUDGE SECONDARY TREATMENT FACILITIES



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

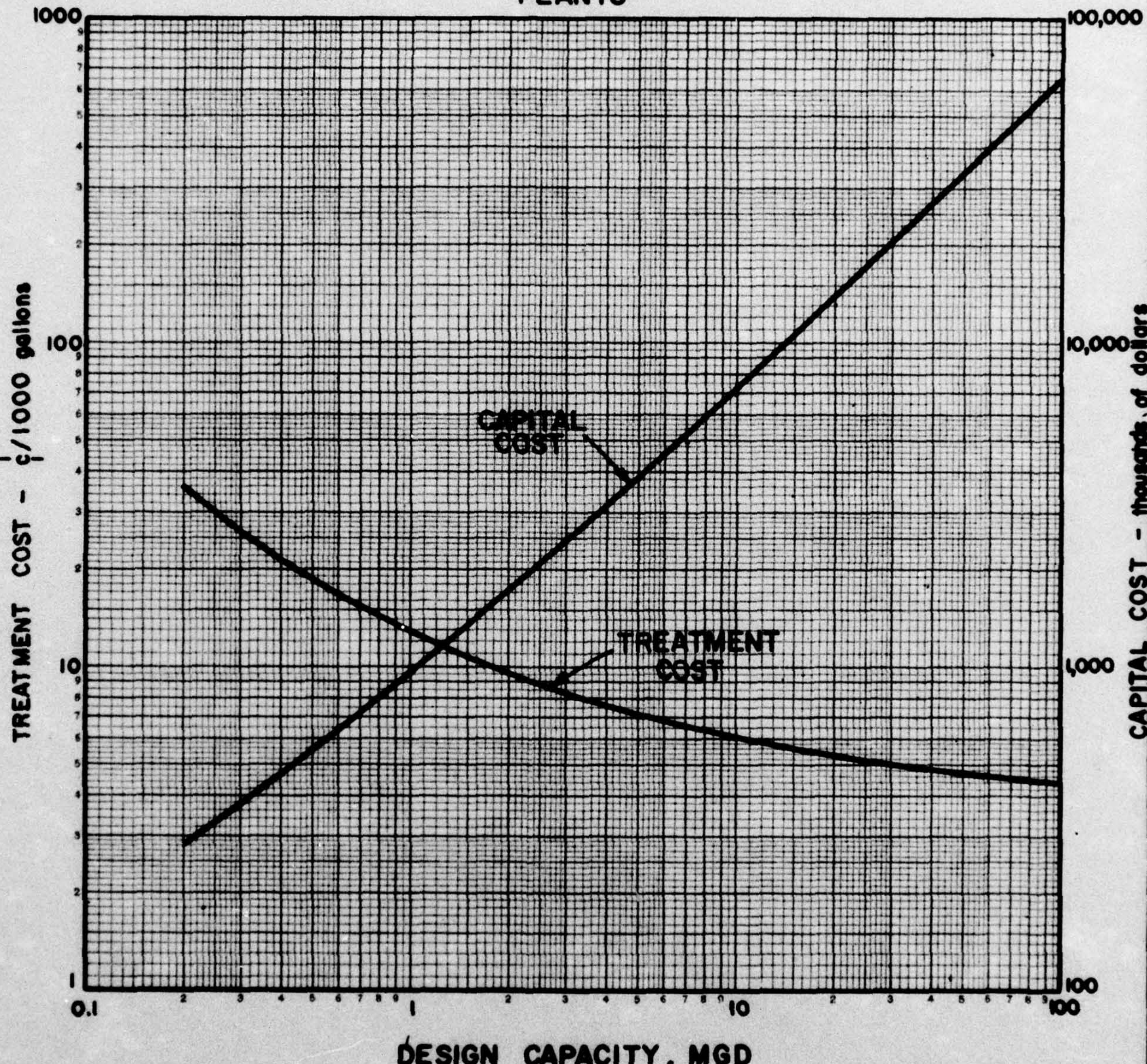
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

COST OF CONVENTIONAL ACTIVATED SLUDGE SECONDARY TREATMENT FACILITIES

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

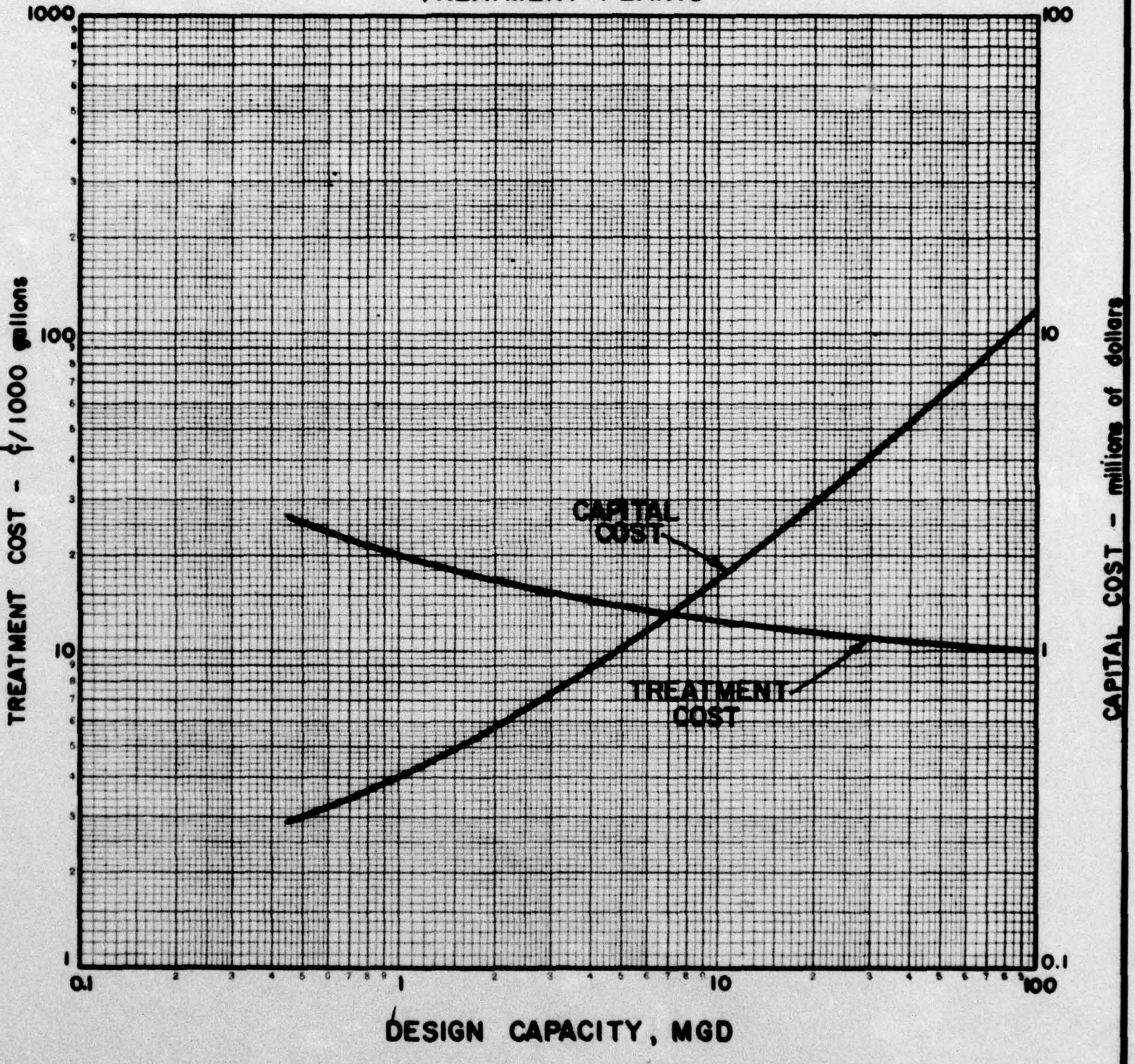
PLATE: TA-1-4

TRICKLING FILTER SECONDARY TREATMENT PLANTS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS
COST OF TRICKLING FILTER SECONDARY TREATMENT FACILITIES
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-I-6

PHYSICAL - CHEMICAL SECONDARY TREATMENT PLANTS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

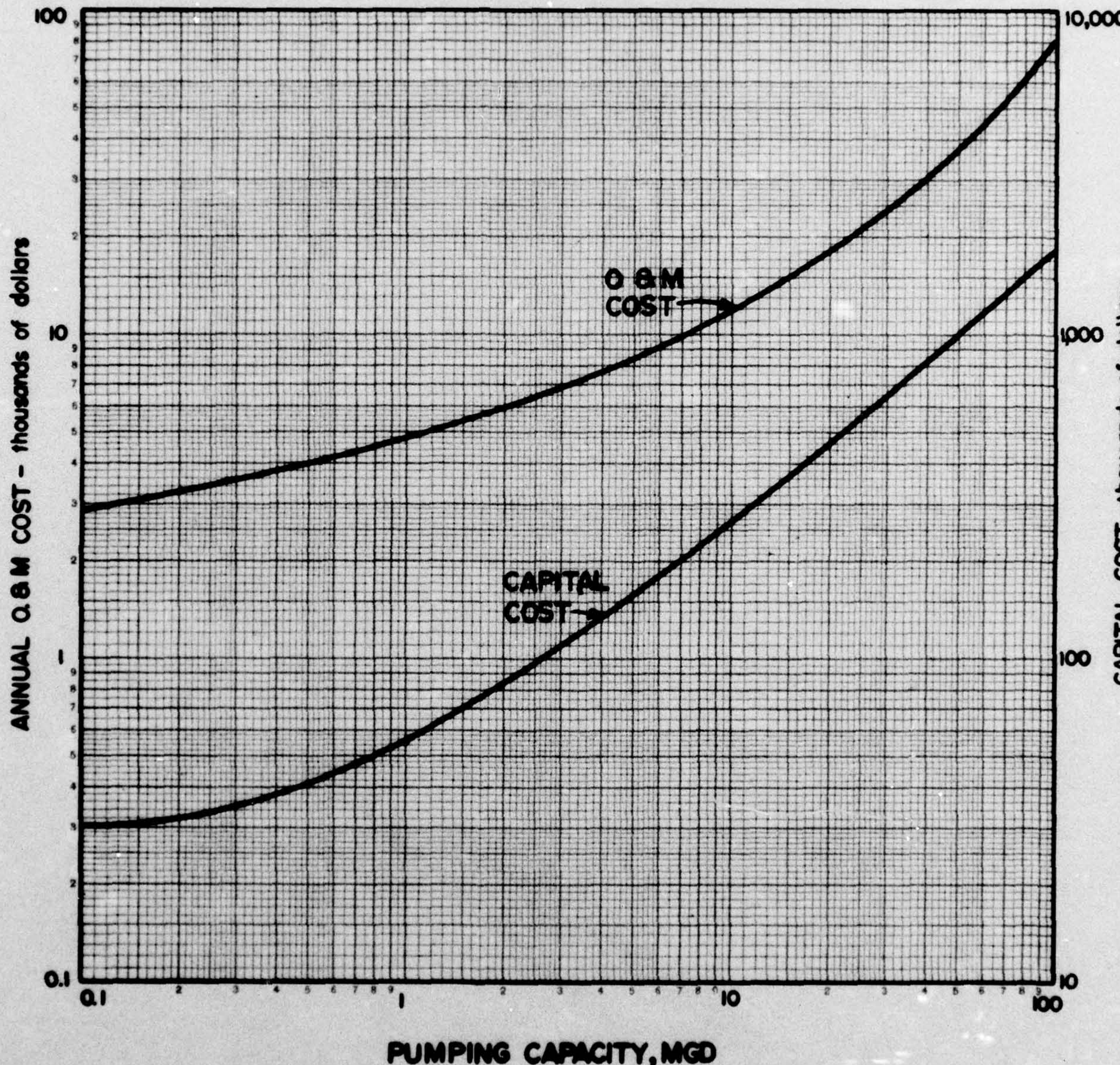
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

COST OF PHYSICAL - CHEMICAL SECONDARY TREATMENT FACILITIES

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA - 1 - 6

RAW WASTEWATER PUMPING



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

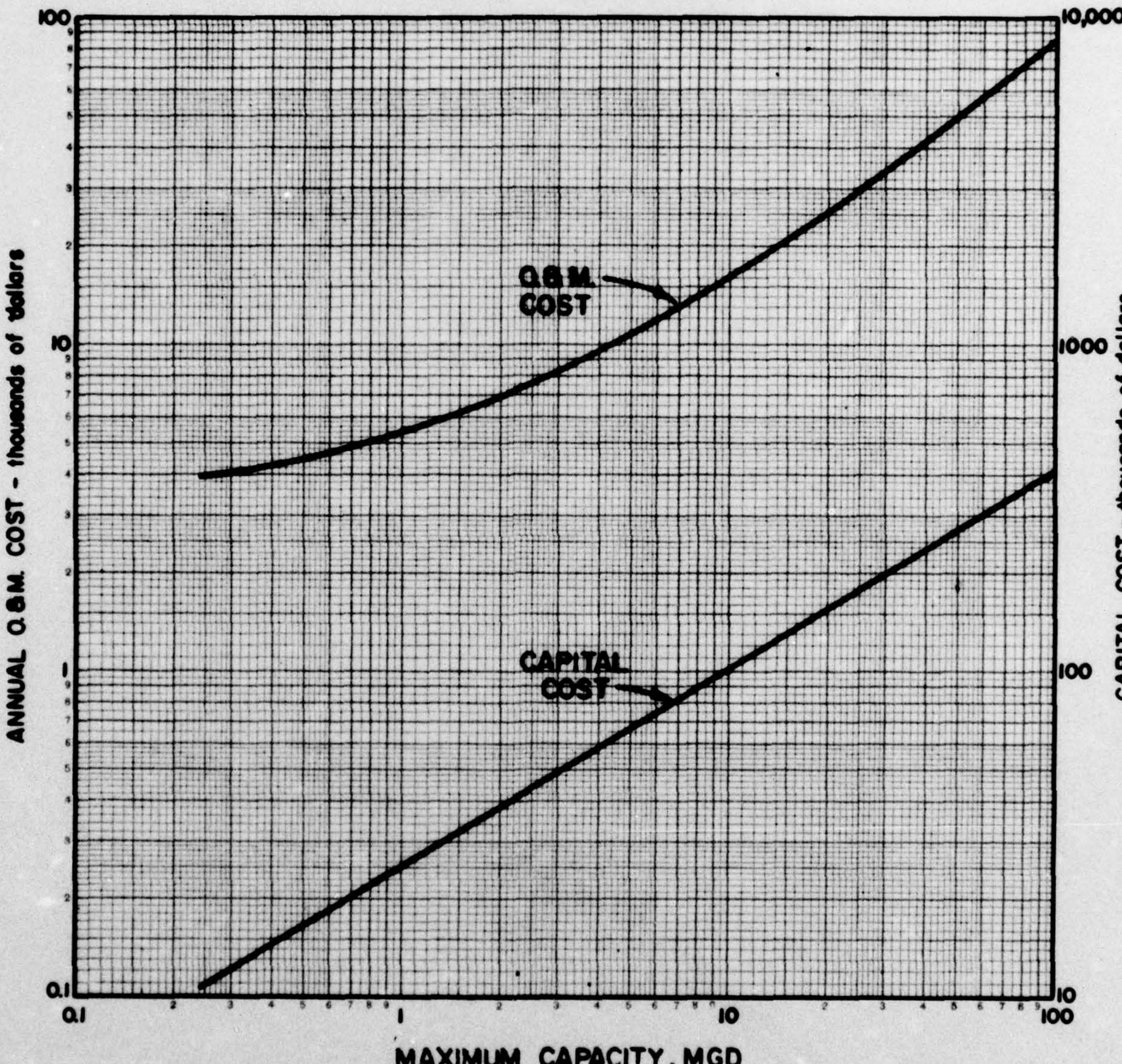
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

RAW WASTEWATER PUMPING

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

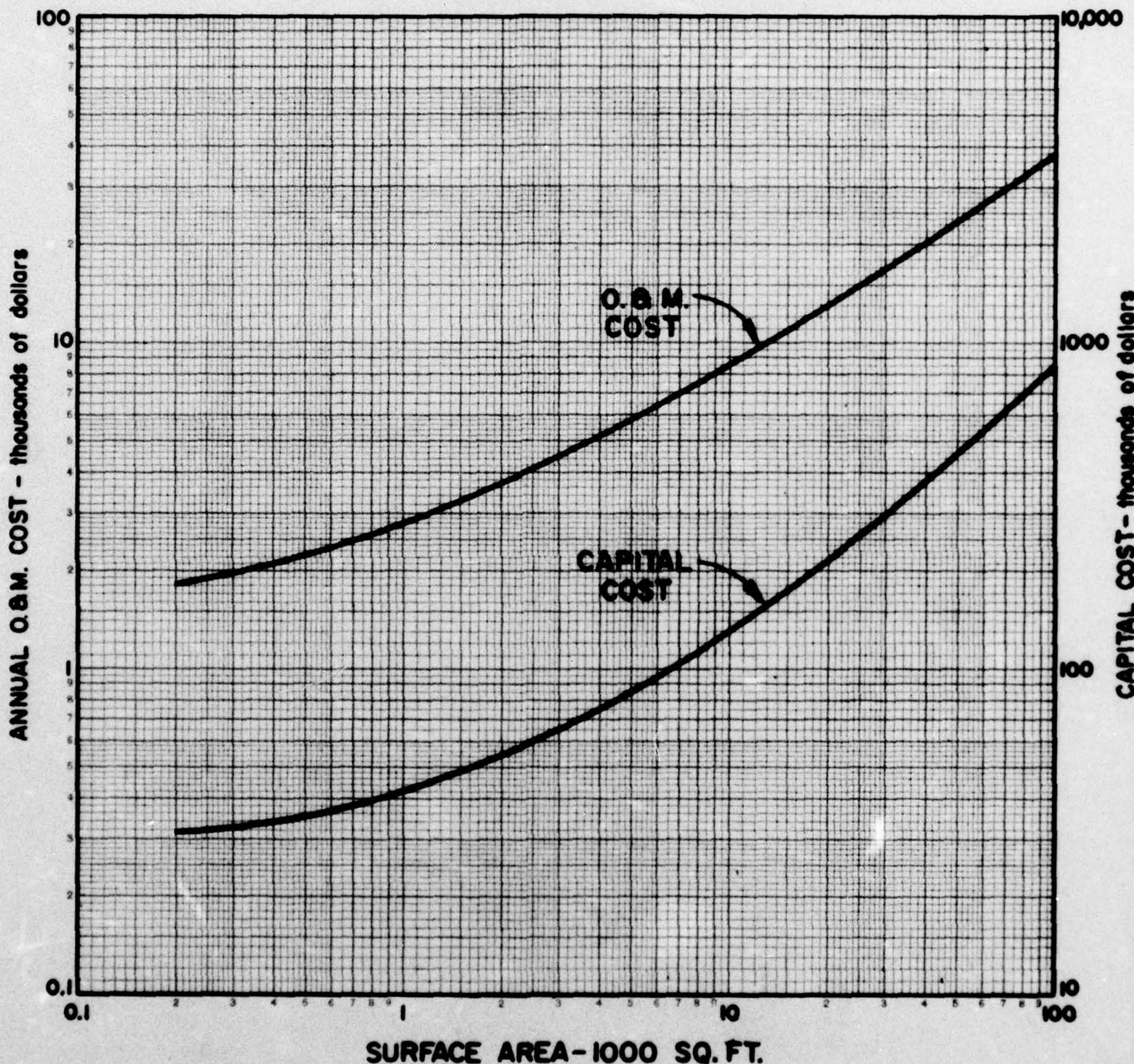
PLATE: TA-1-7

PRELIMINARY TREATMENT
(SCREENING, GRIT REMOVAL, AND FLOW MEASUREMENT)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
PRELIMINARY TREATMENT
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-1-8

SEDIMENTATION



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

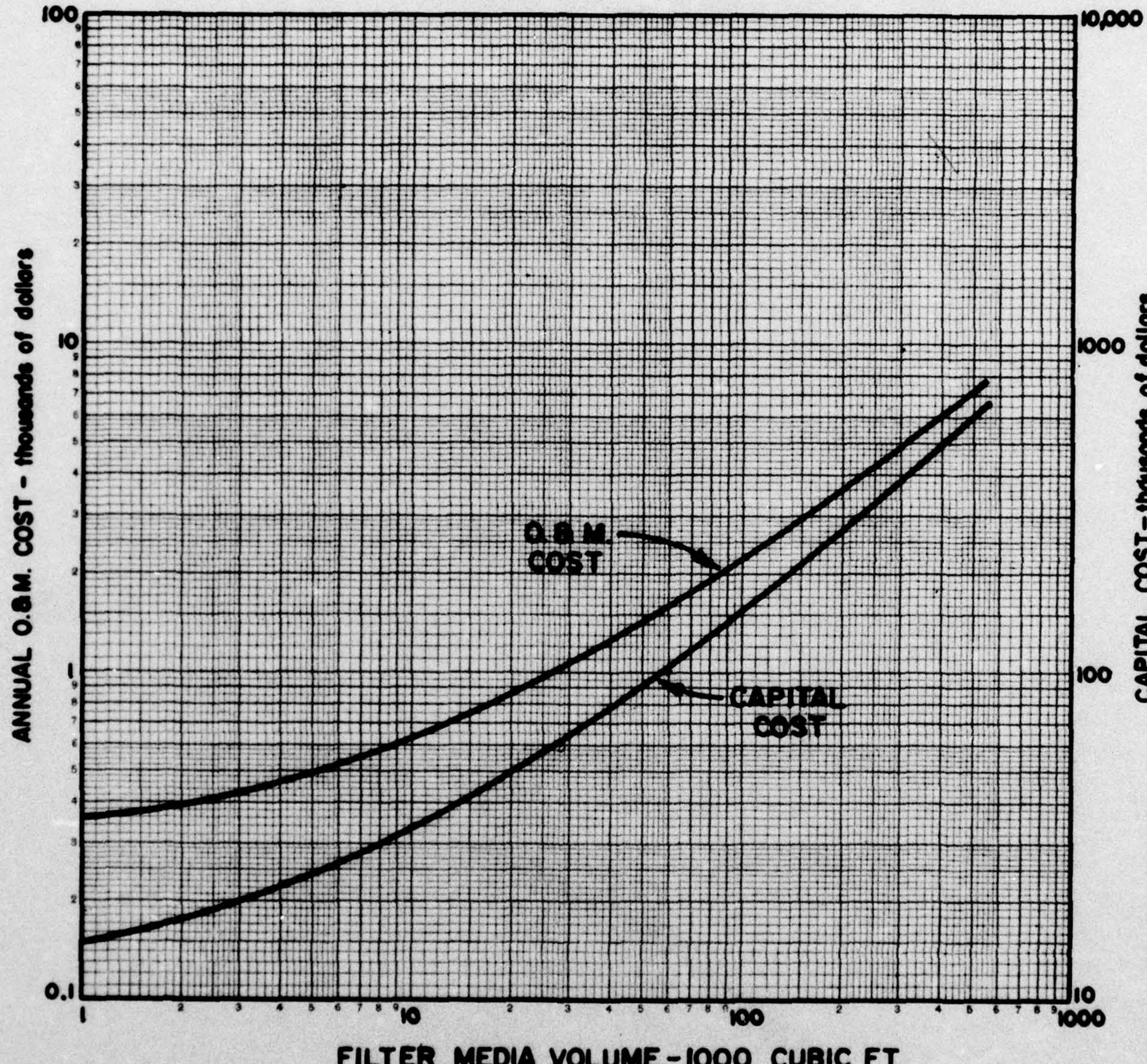
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

SEDIMENTATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-9

TRICKLING FILTERS



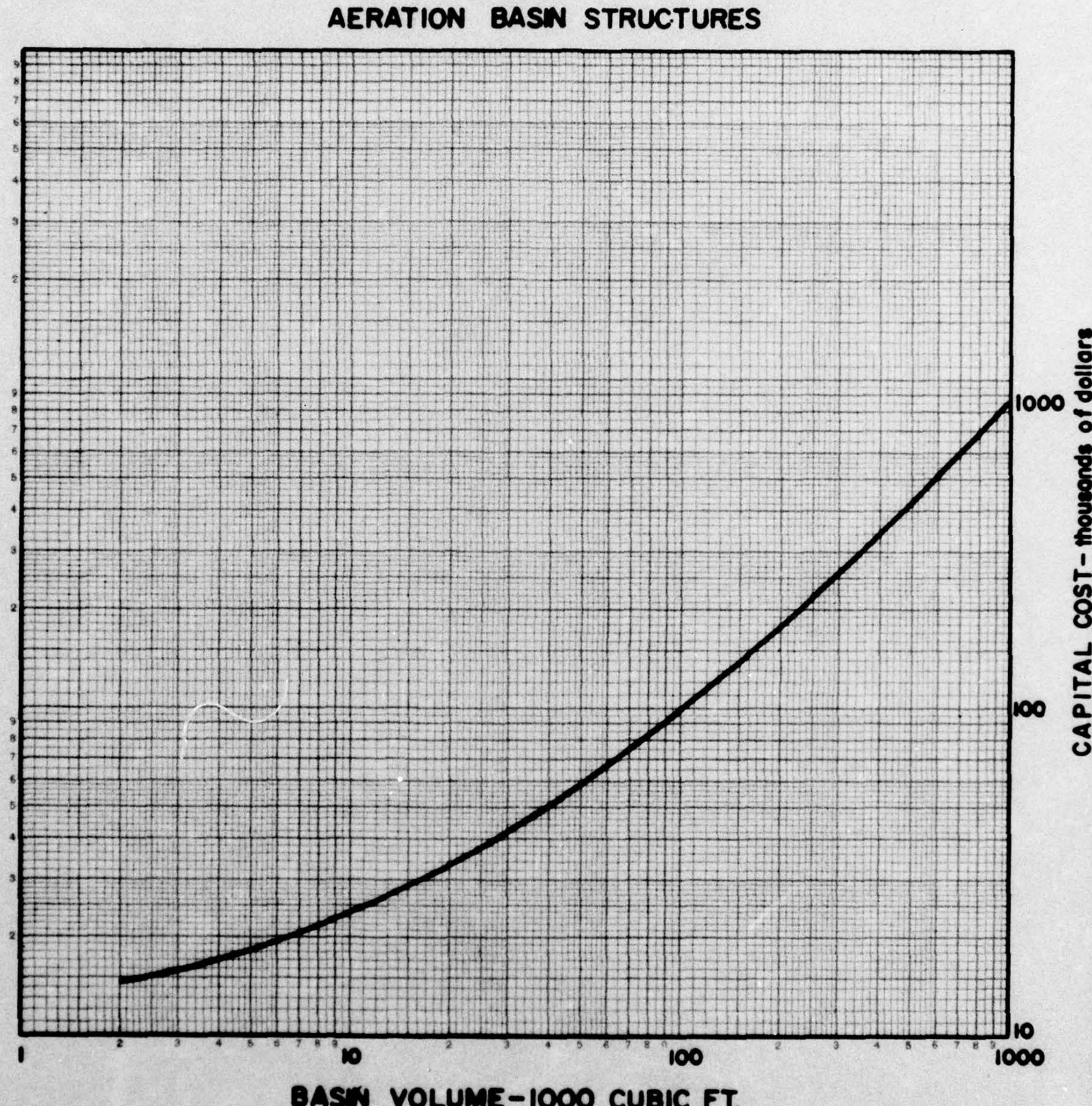
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TRICKLING FILTERS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-10



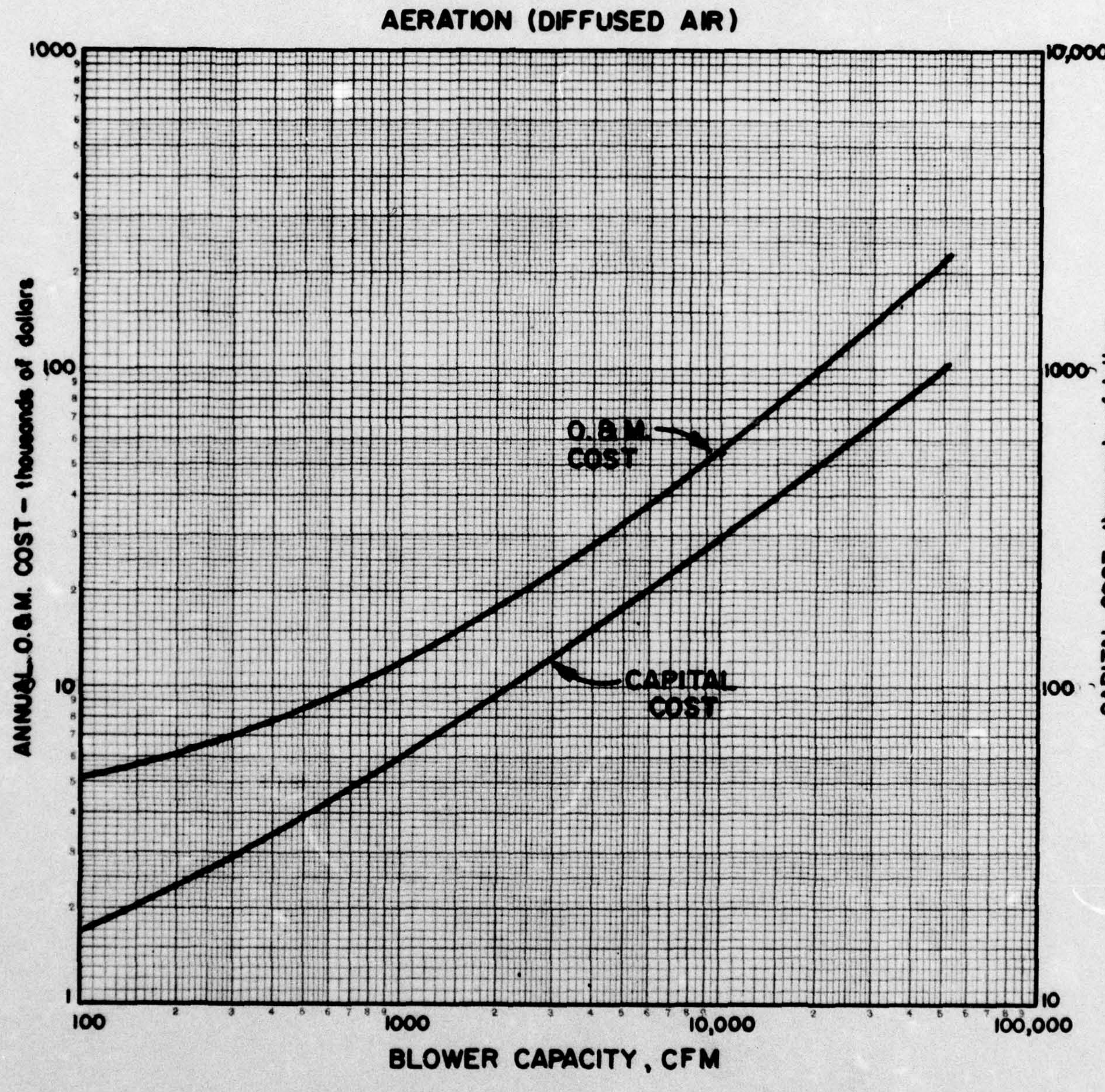
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

AERATION BASIN

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-11



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

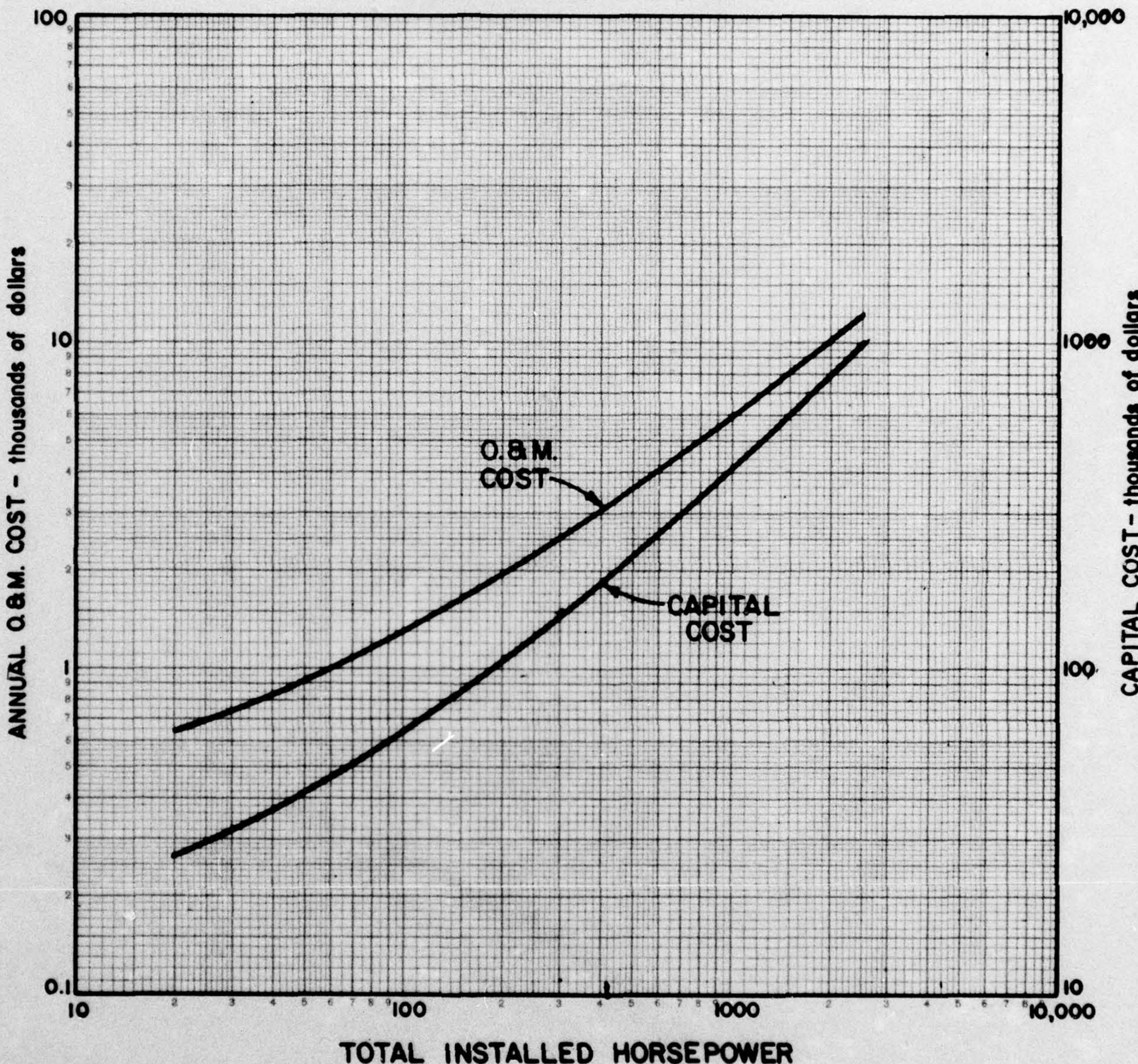
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

AERATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-12

AERATION (MECHANICAL)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

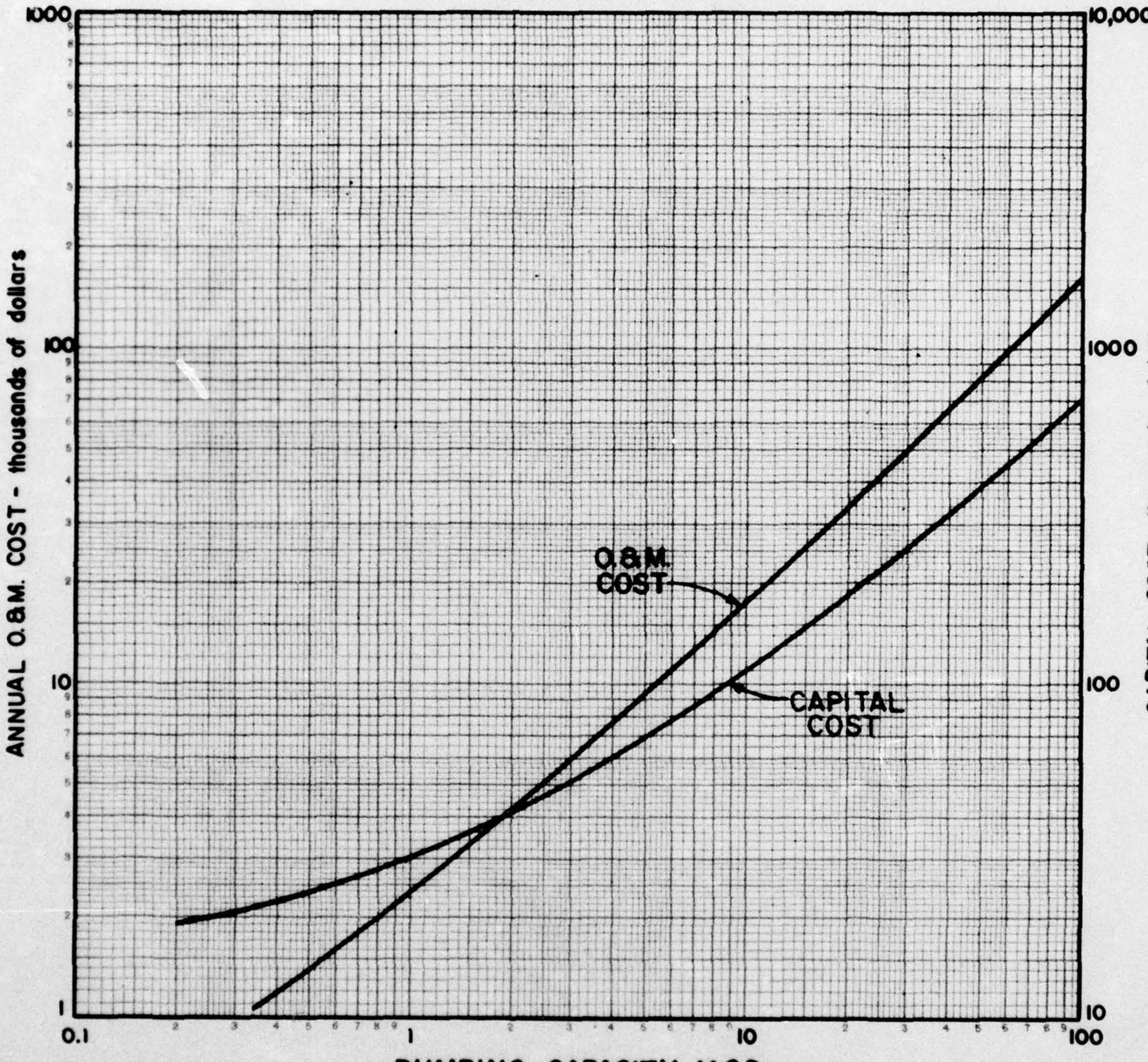
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

AERATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

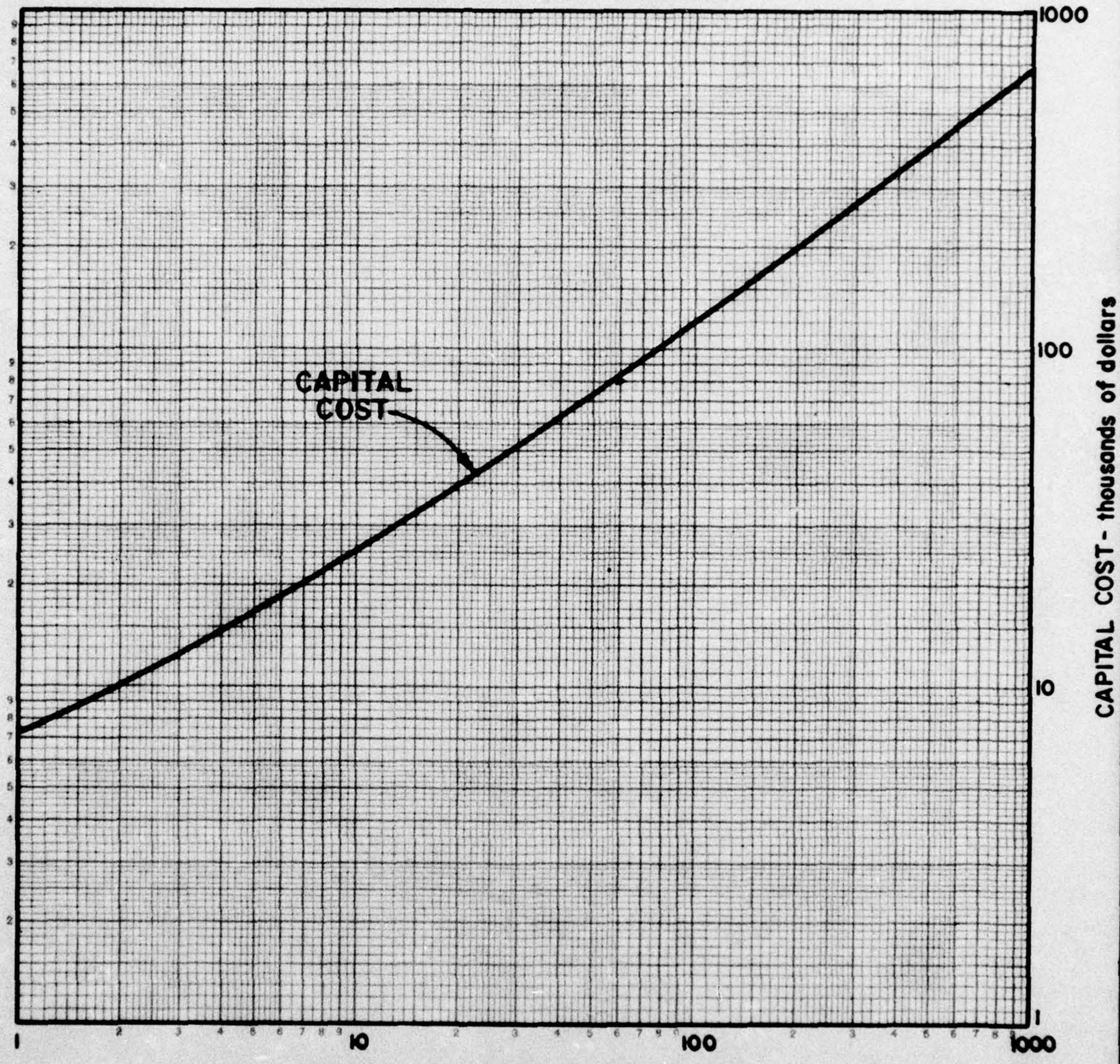
PLATE: TA - I - 13

RECIRCULATION
(INTERMEDIATE PUMPING)



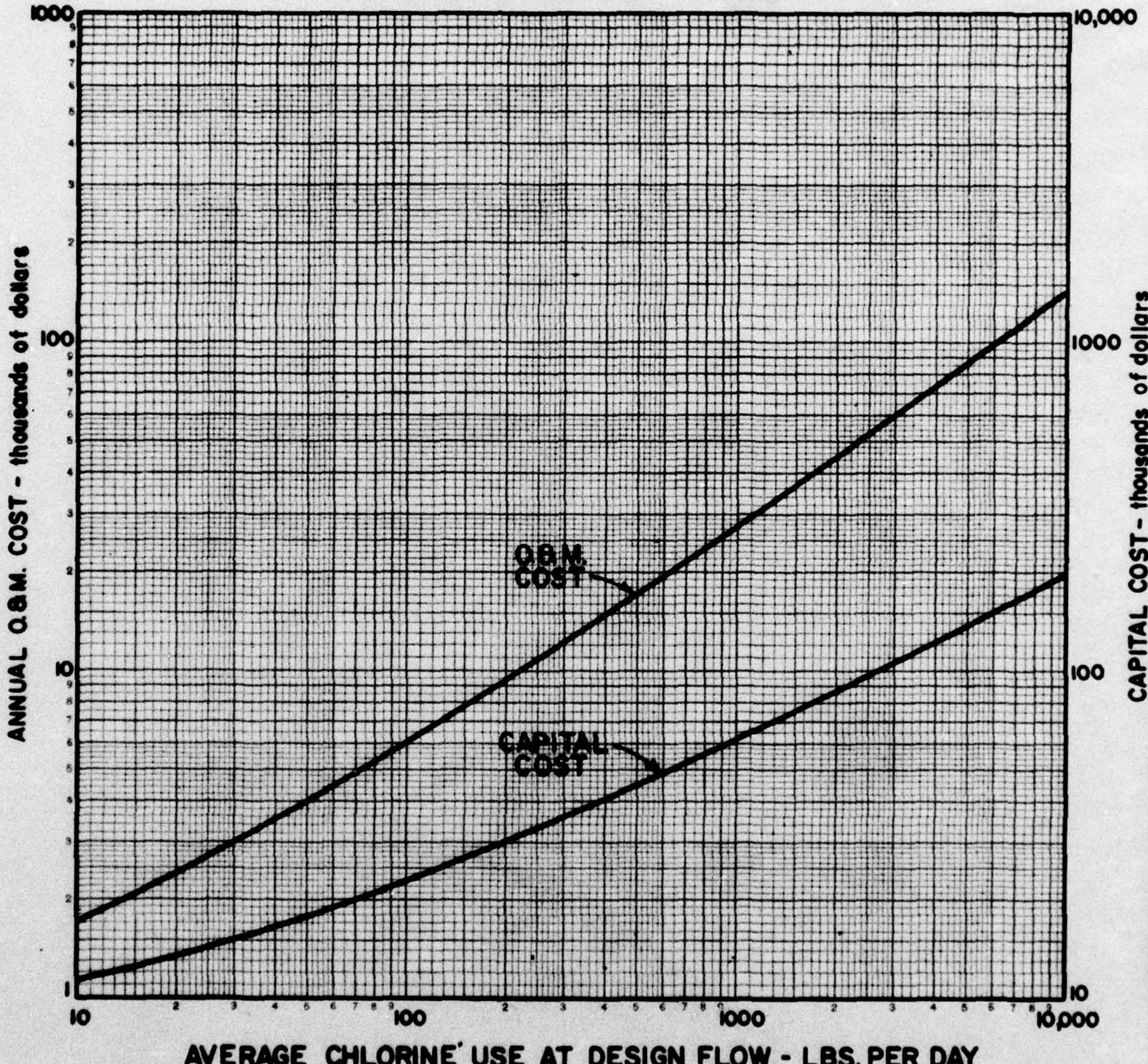
U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
RECIRCULATION
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-1-14

CHLORINE CONTACT BASINS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
CHLORINE CONTACT BASINS
[illegible]ER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA - 1 - 15

CHLORINATION FEED SYSTEMS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

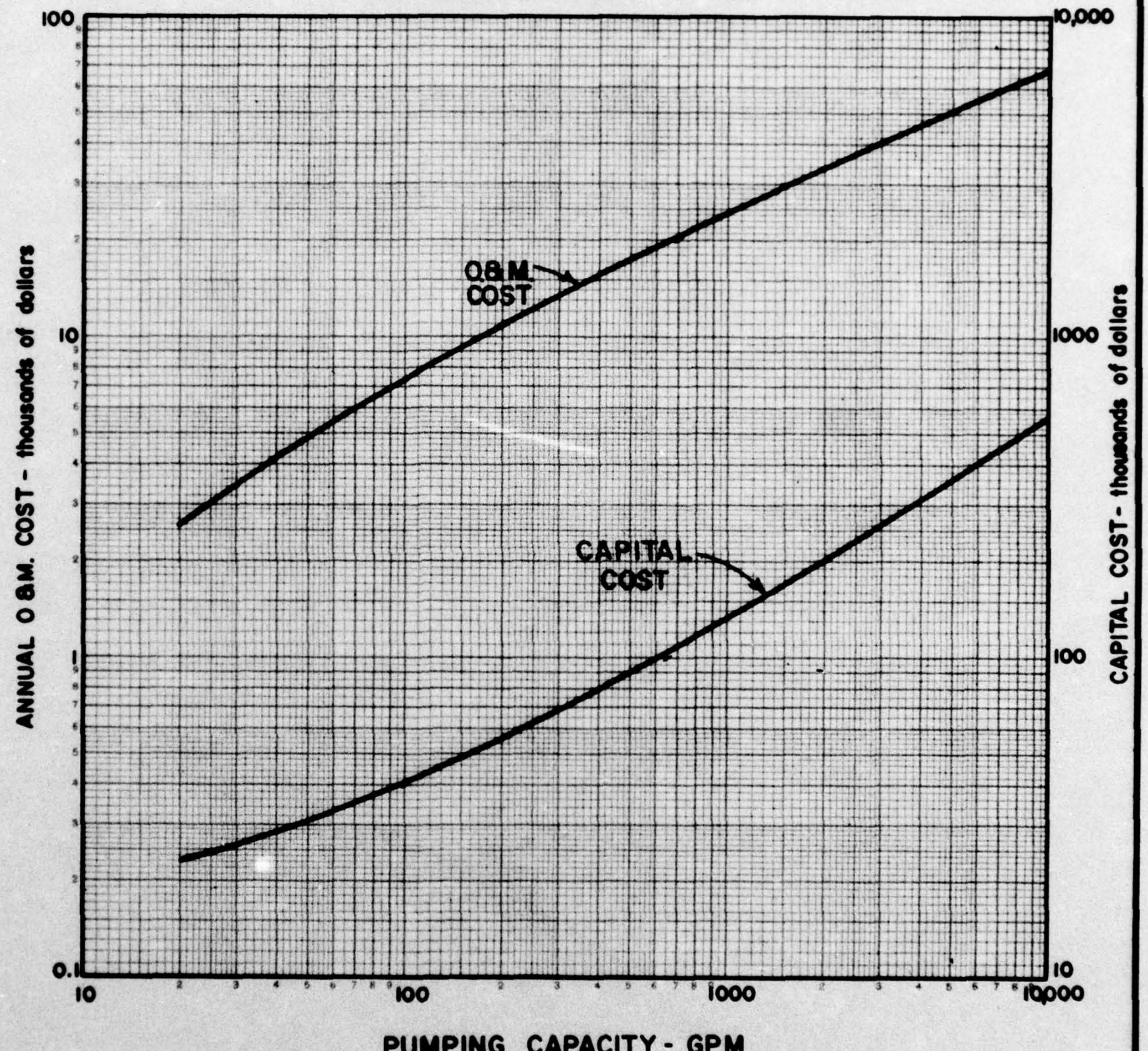
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

CHLORINATION FEED SYSTEMS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-16

PRIMARY SLUDGE PUMPING



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

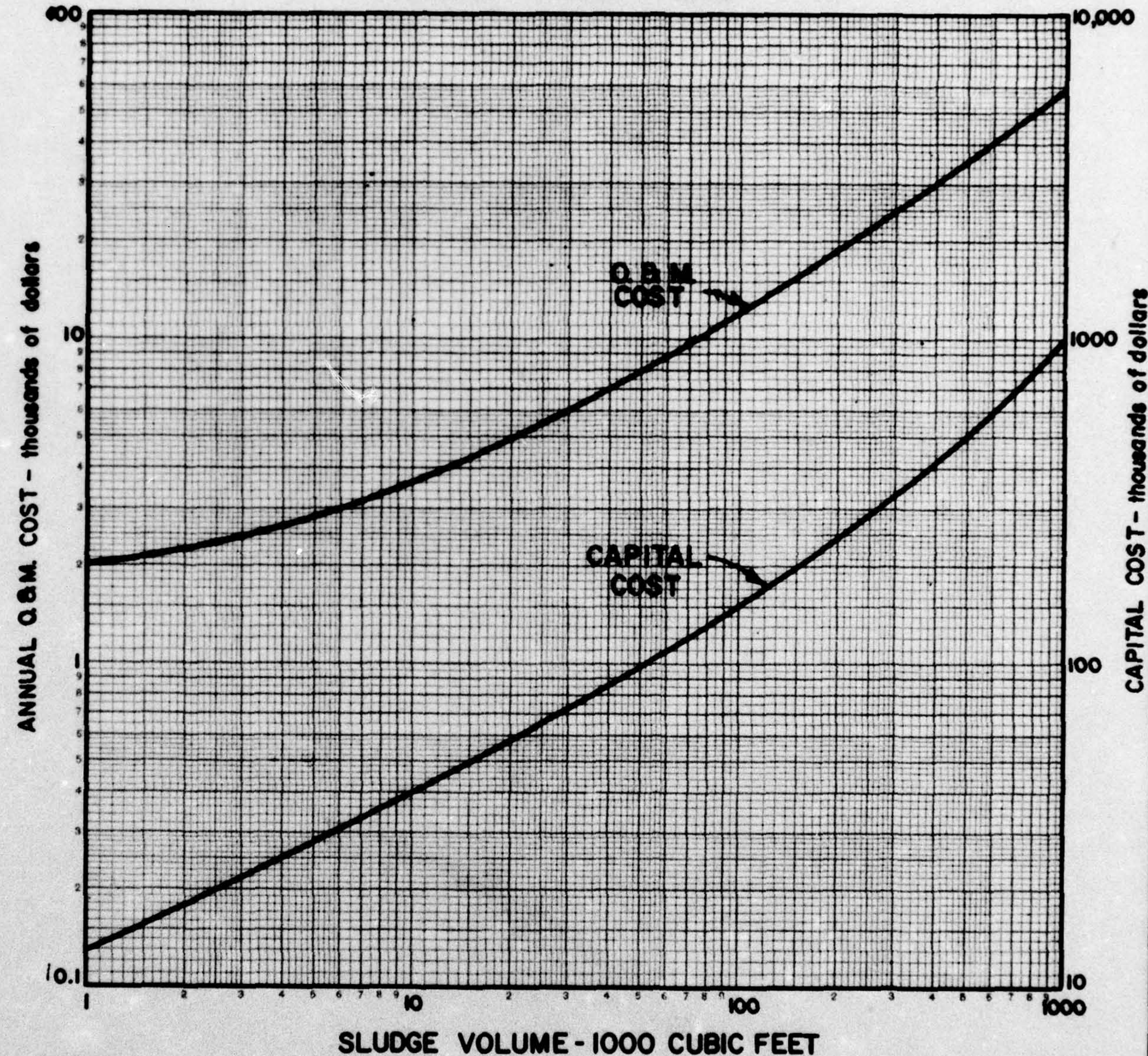
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

PRIMARY SLUDGE PUMPING

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-17

SLUDGE HOLDING TANKS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

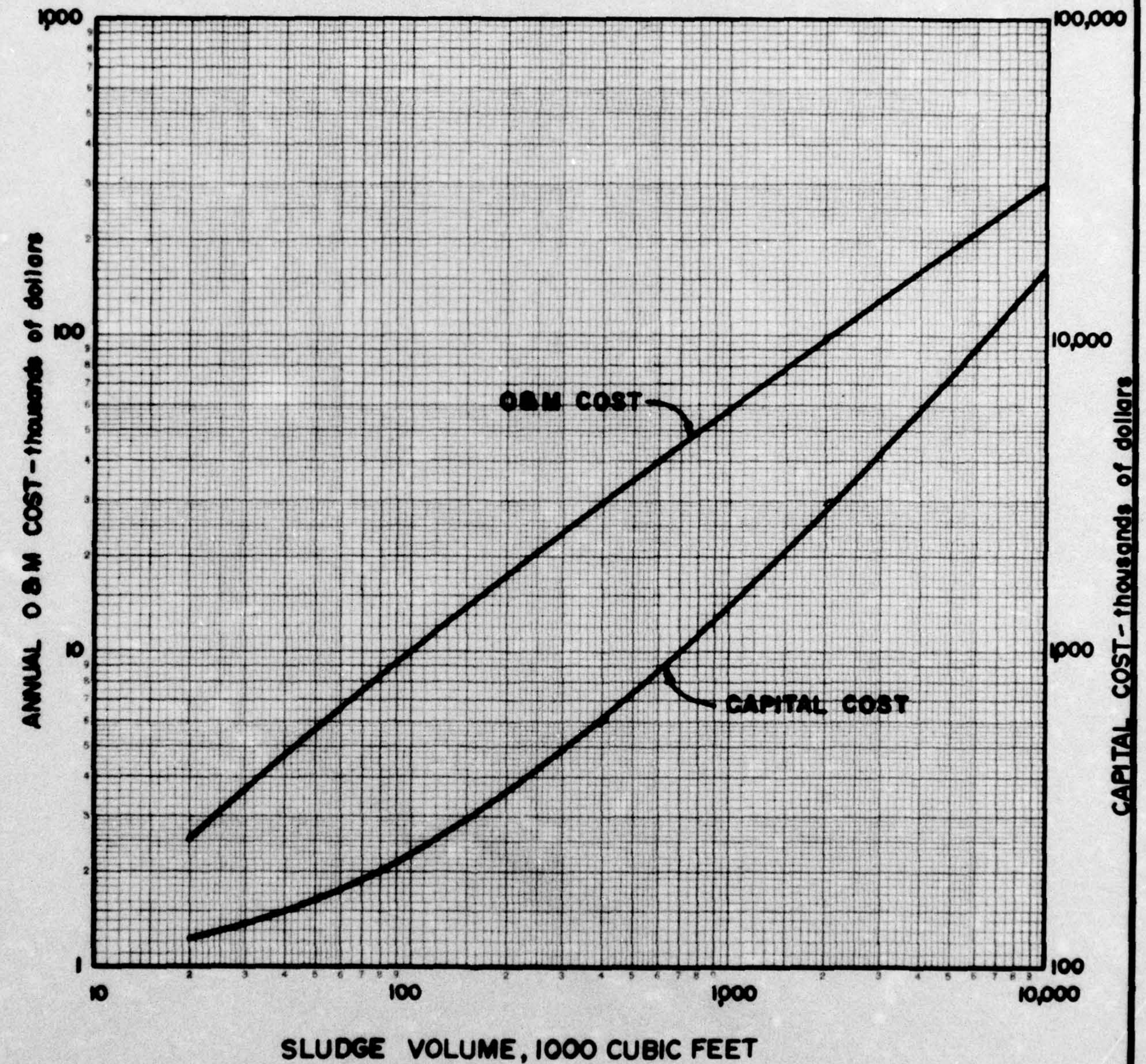
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

SLUDGE HOLDING TANKS

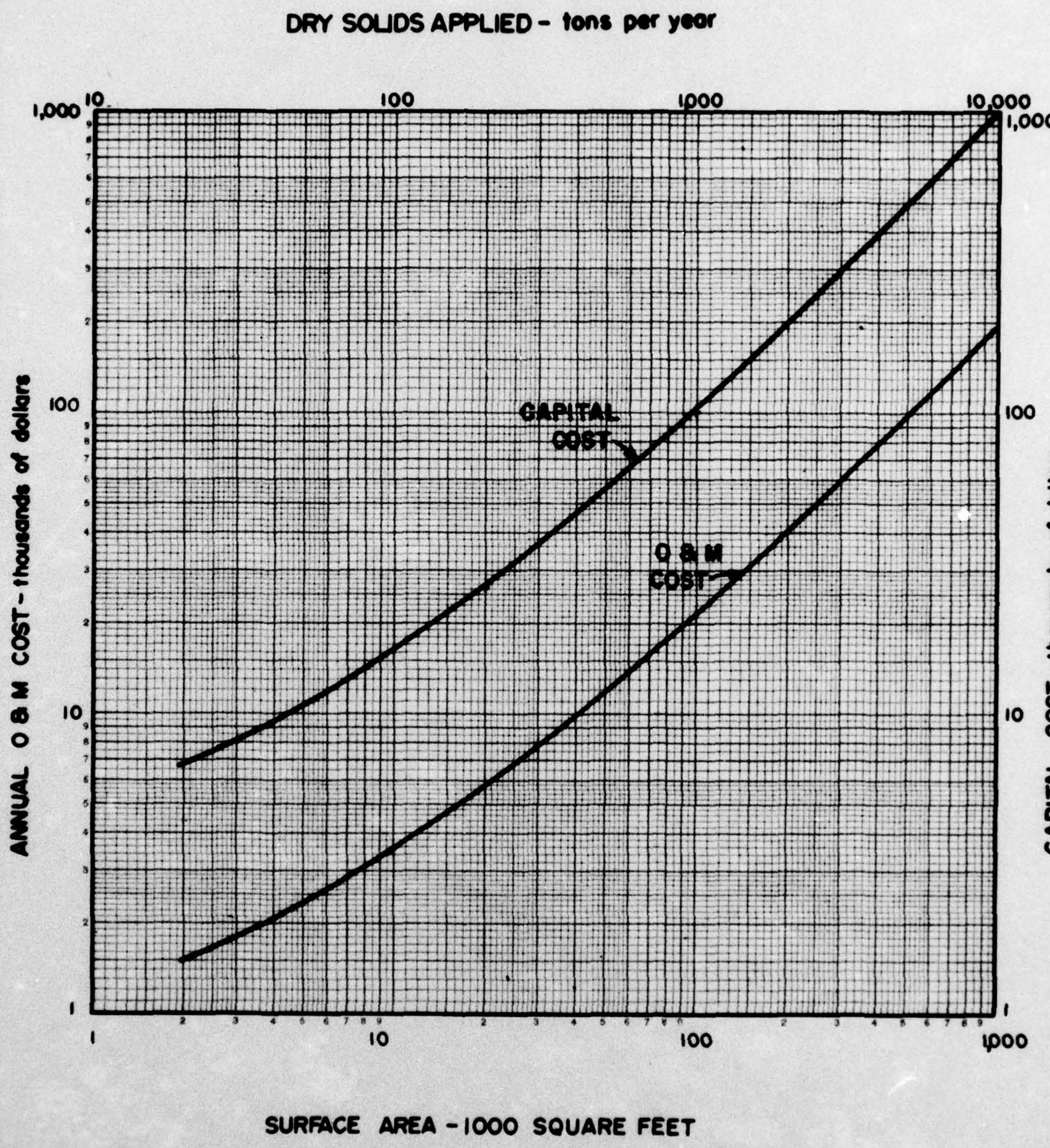
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-18

SLUDGE DIGESTION



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
SLUDGE DIGESTION
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-1-19



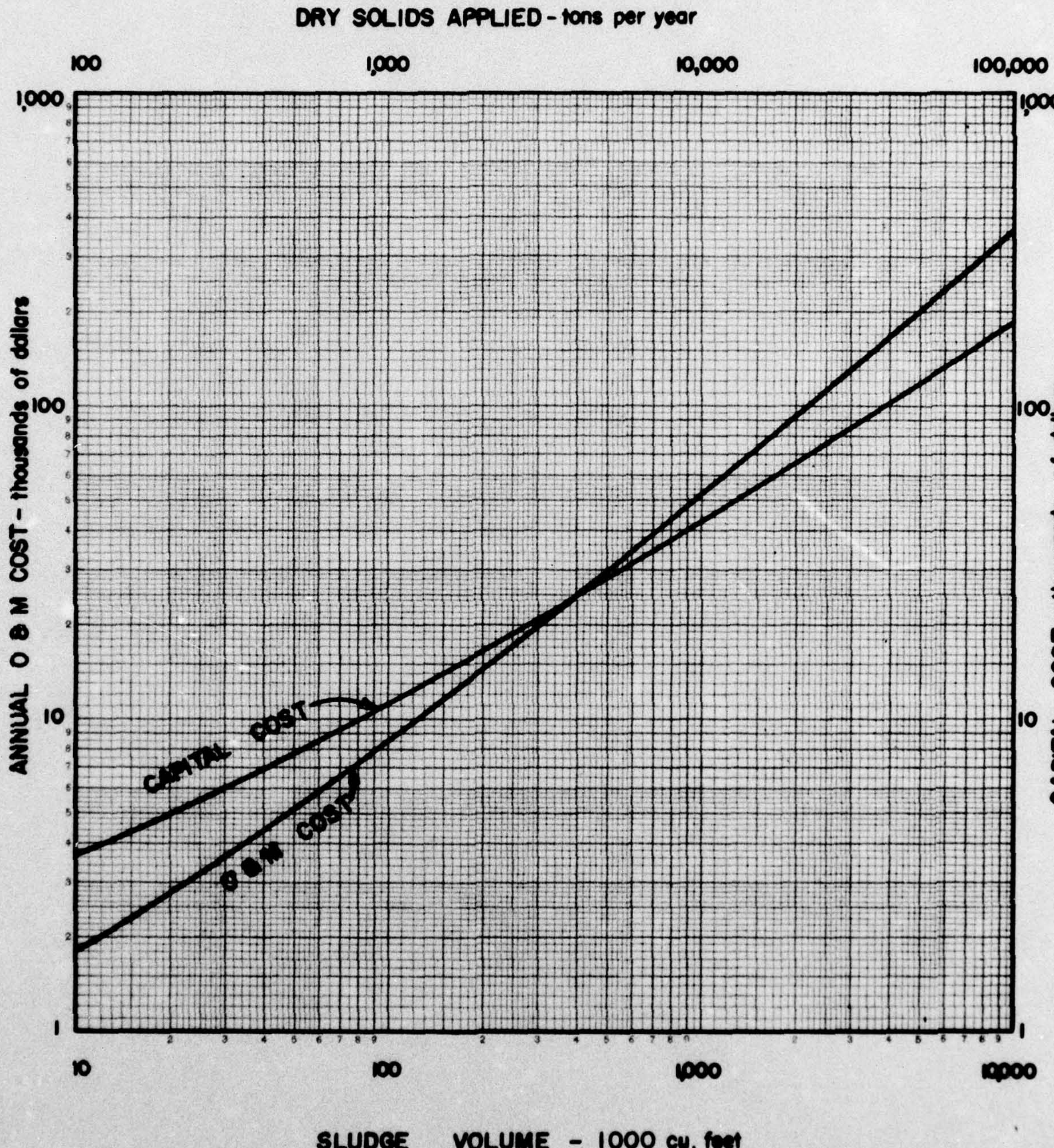
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

SLUDGE DRYING BEDS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-20



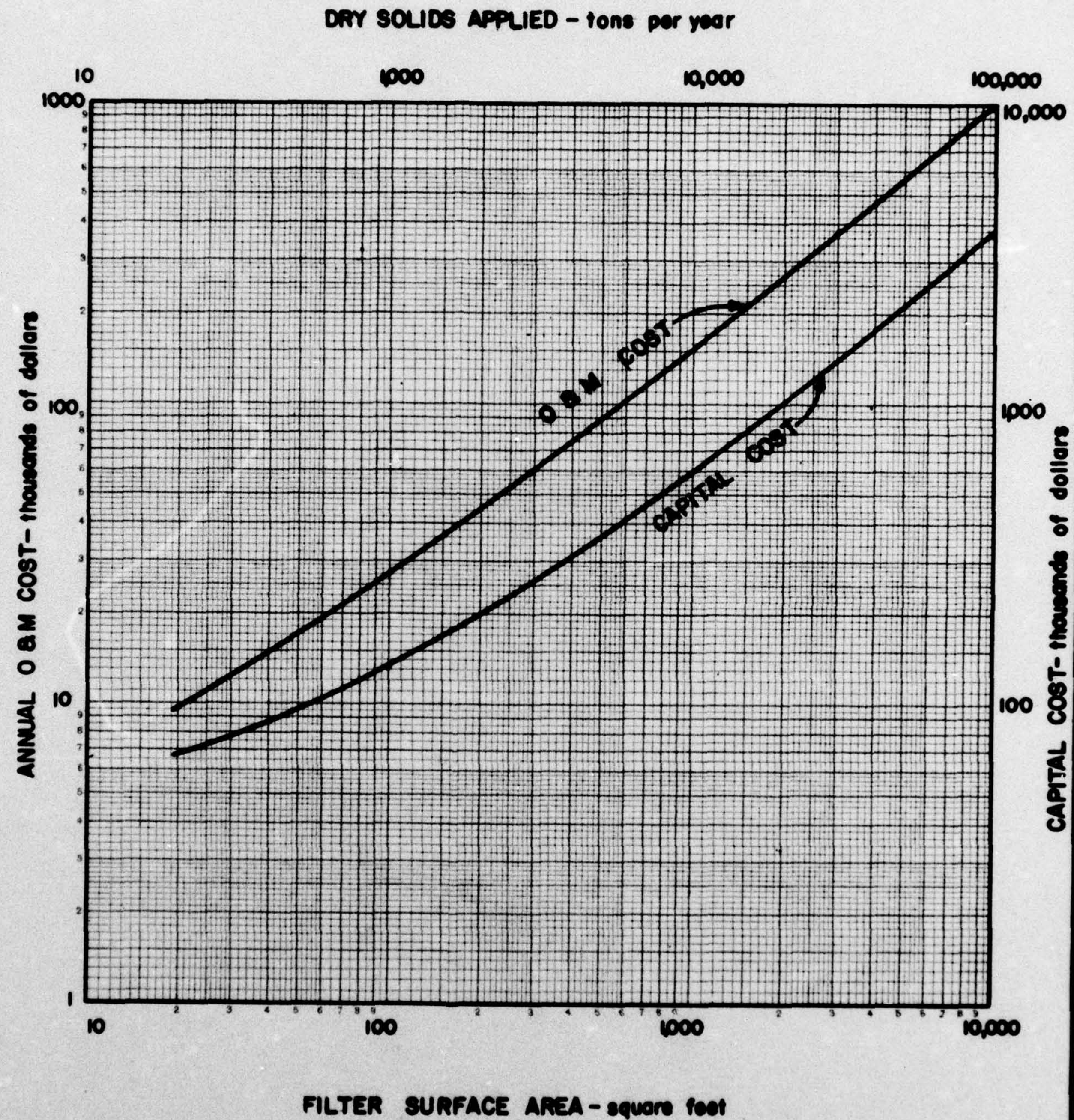
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

SLUDGE LAGOONS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-21



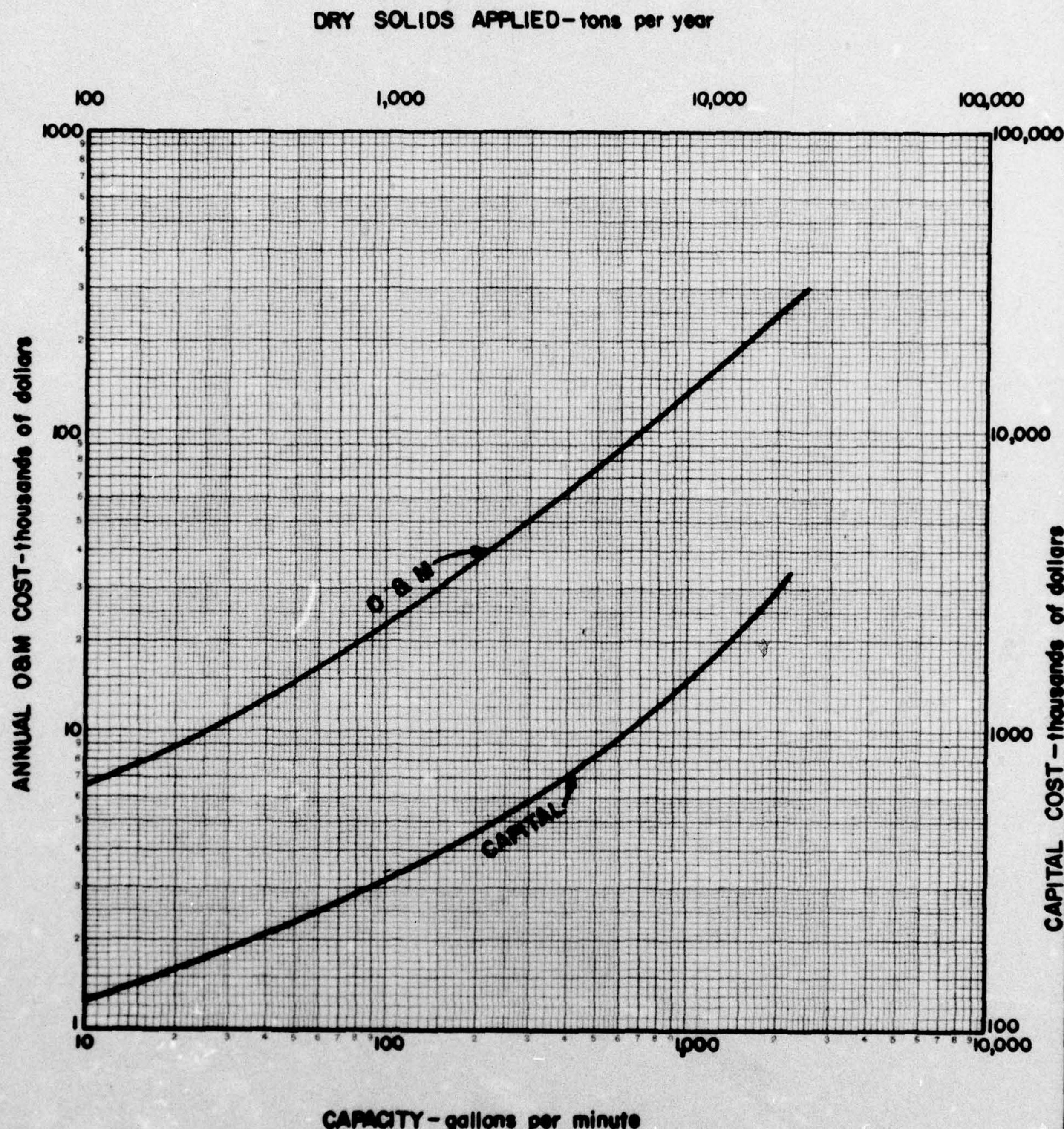
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

VACUUM FILTRATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-22



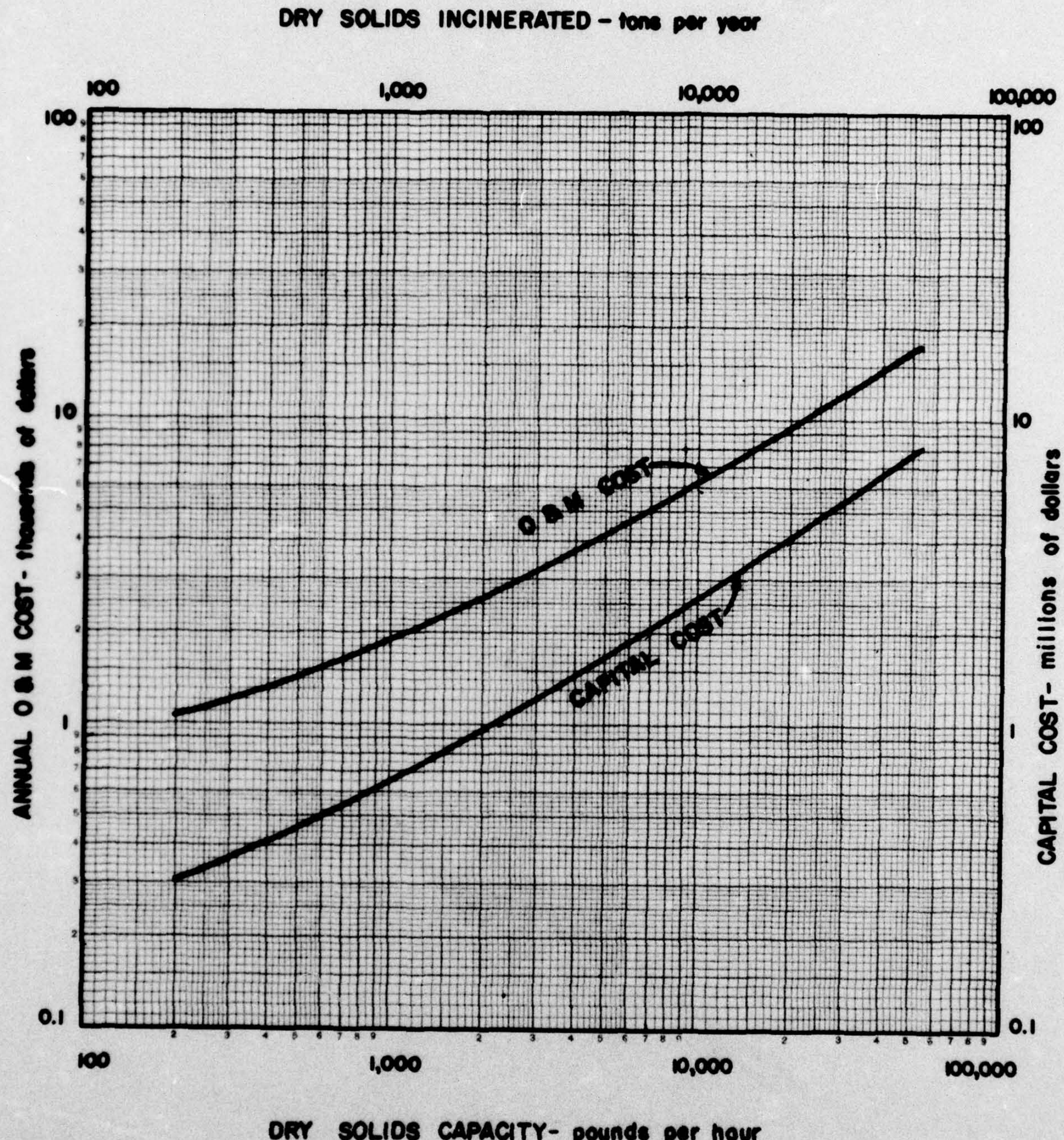
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

CENTRIFUGATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-23



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

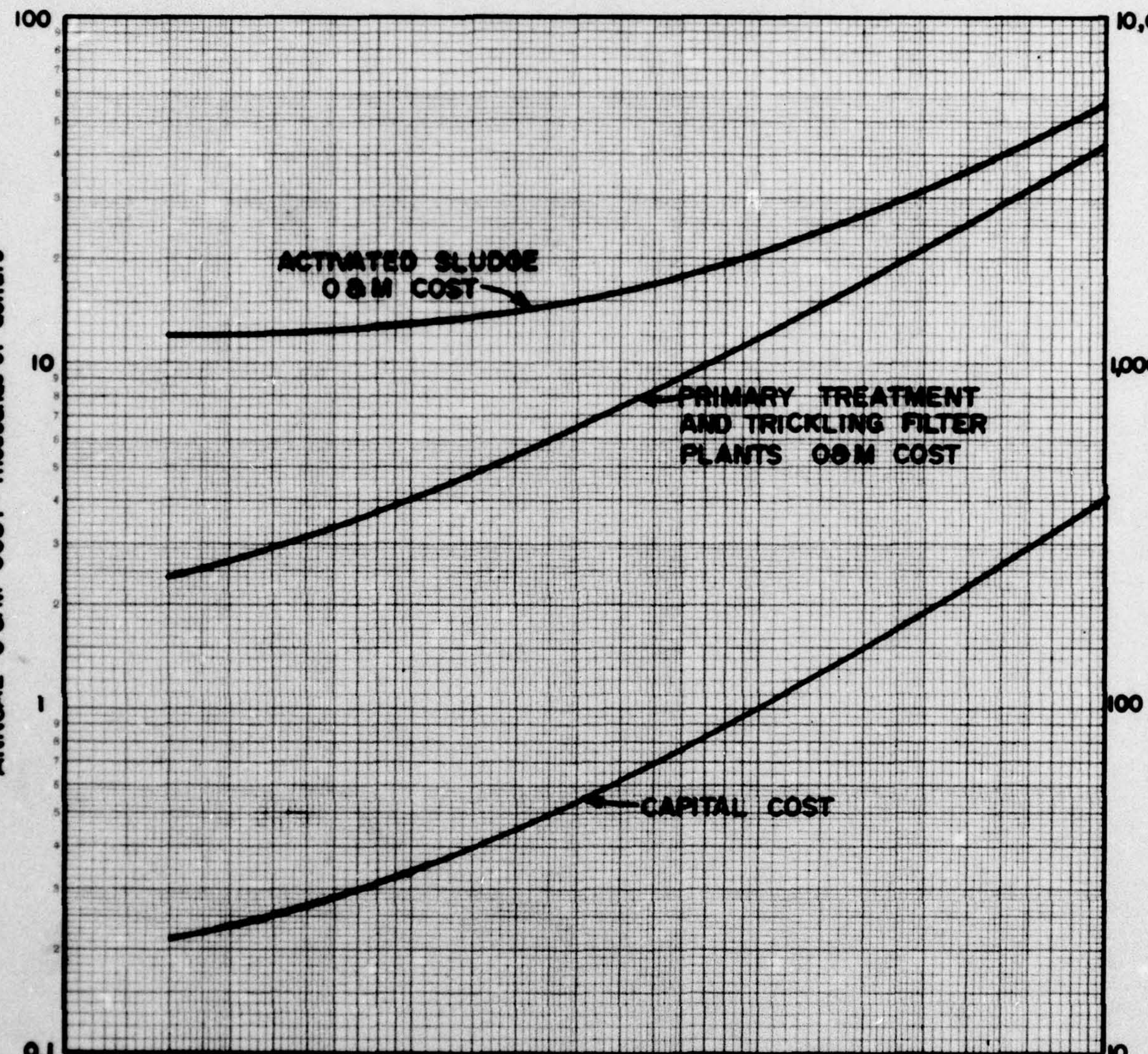
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

MULTIPLE HEARTH
INCINERATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-24

ADMINISTRATION AND LABORATORY



PLANT DESIGN CAPACITY, M.G.D.

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

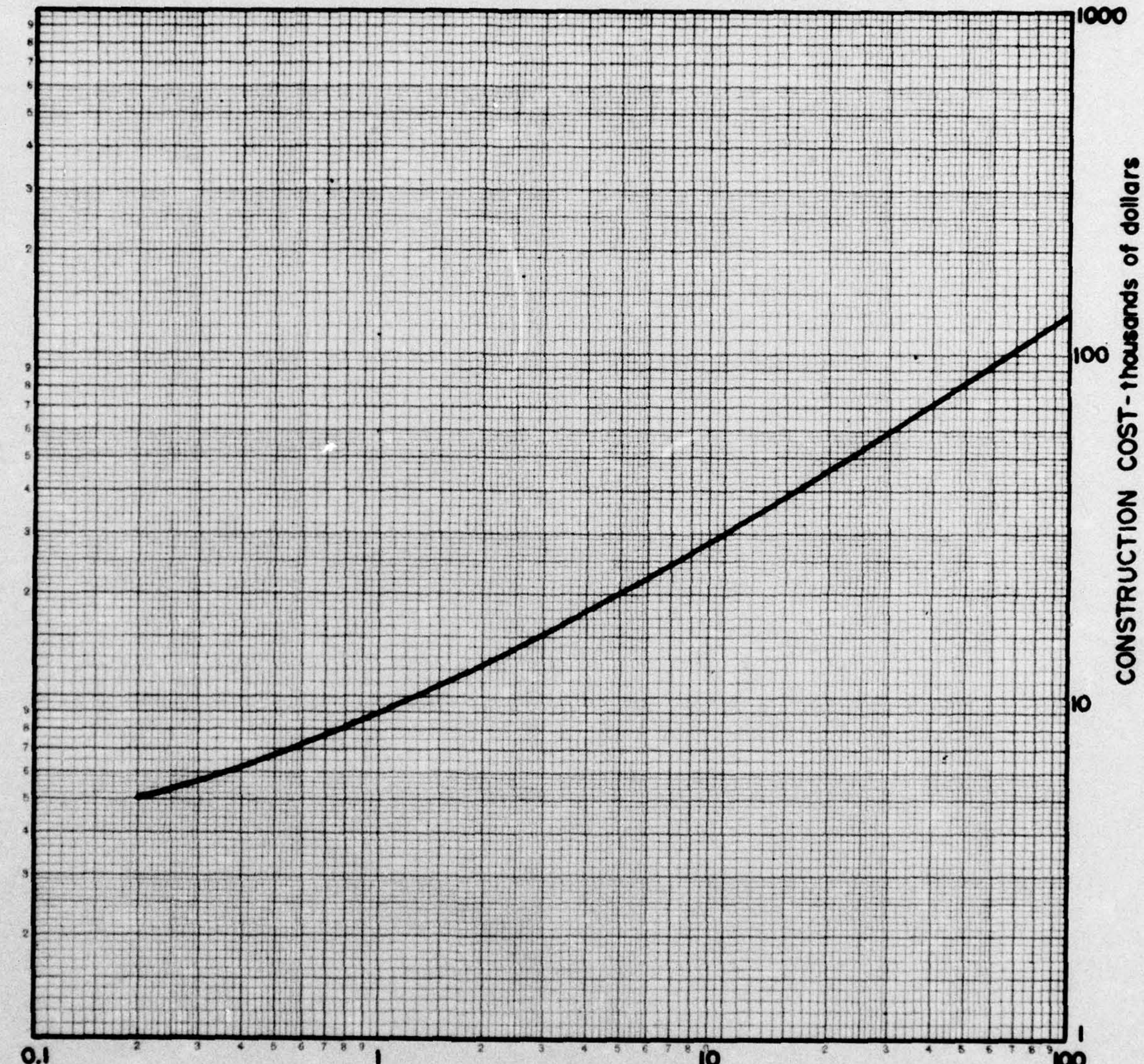
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

ADMINISTRATION AND LABORATORY

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-25

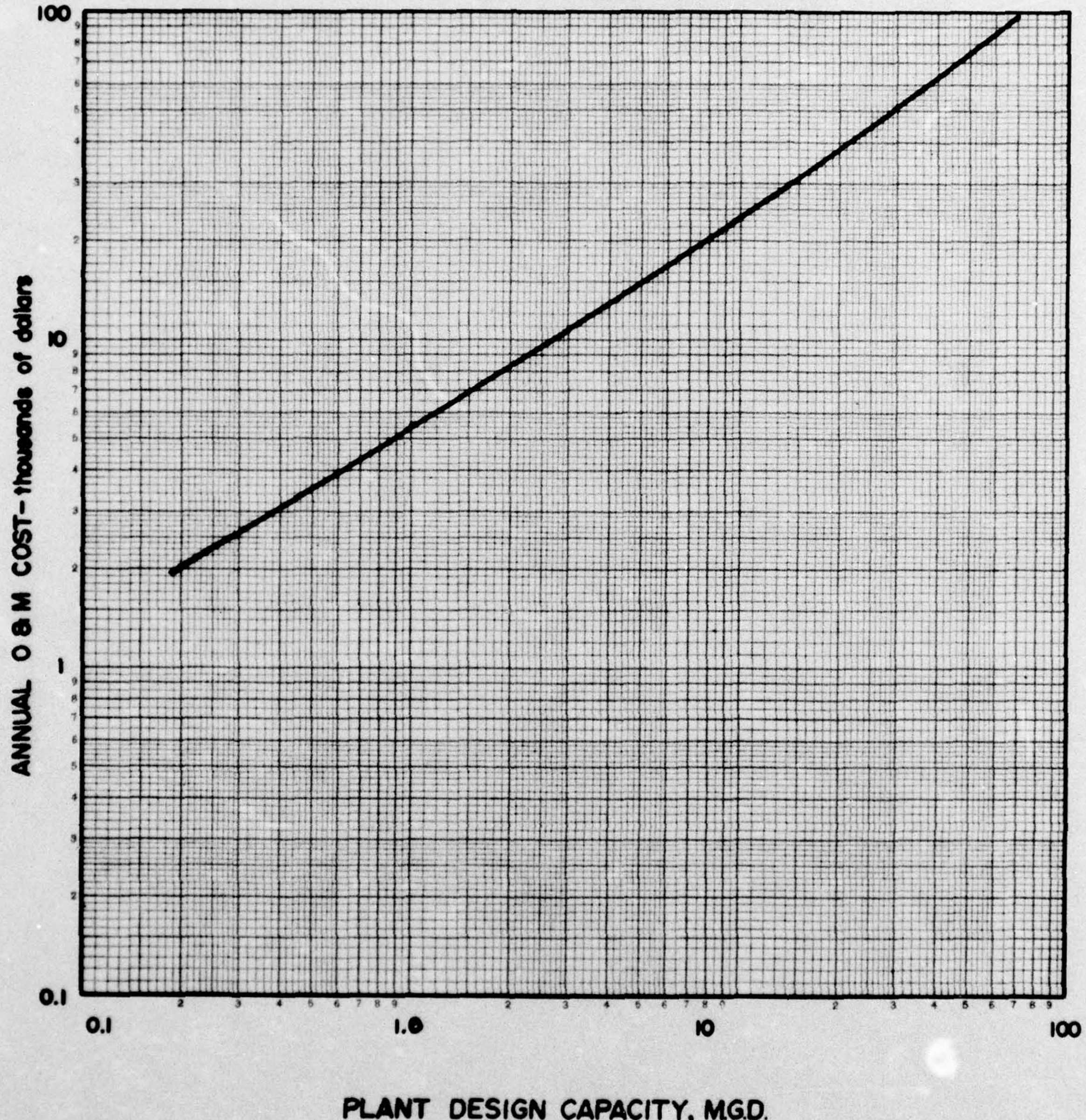
GARAGE AND SHOP FACILITIES



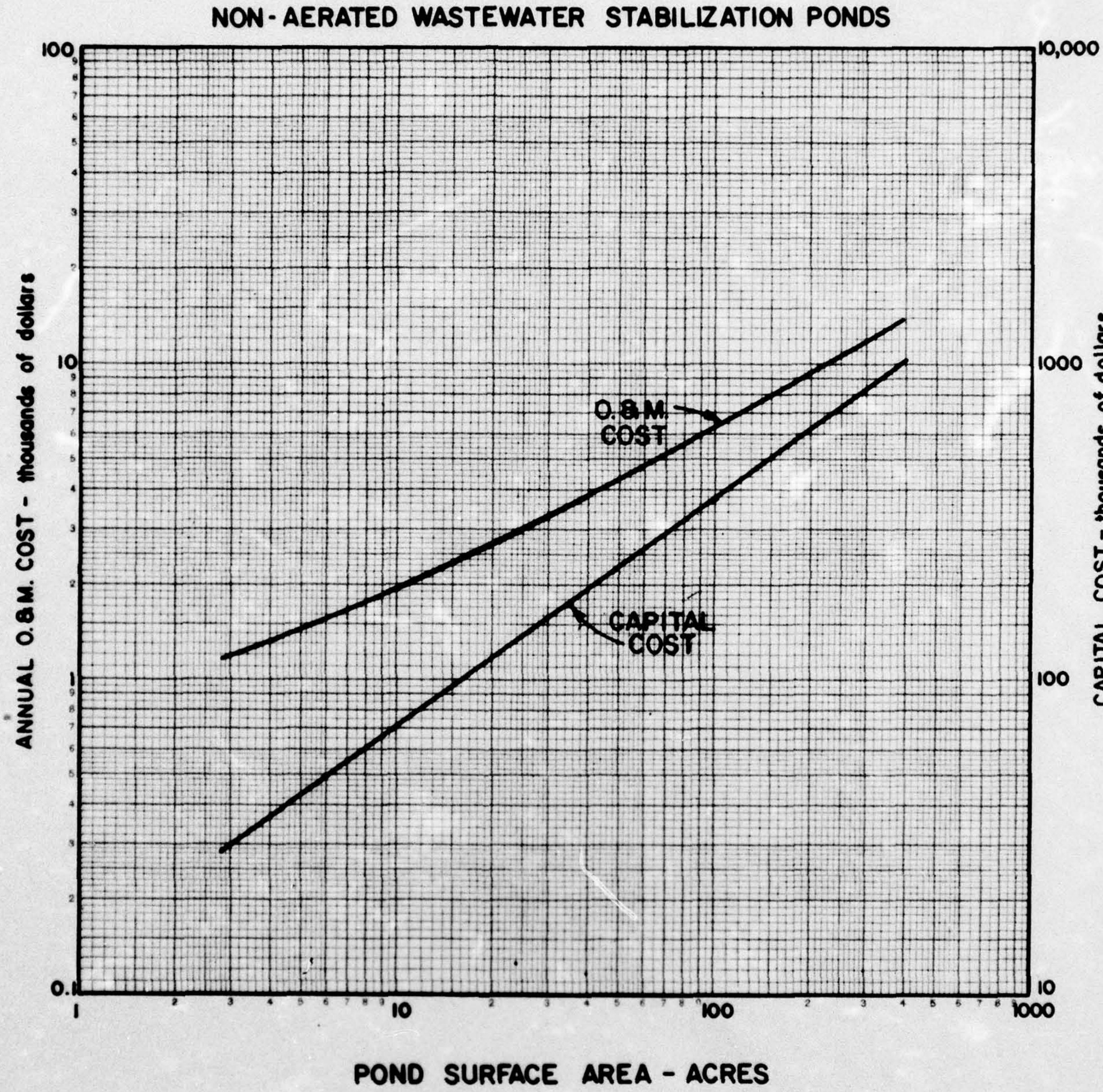
AVERAGE PLANT CAPACITY-M.G.D.

U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
GARAGE AND SHOP FACILITIES
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-1-26

ADMINISTRATION AND GENERAL O & M



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
ADMINISTRATION AND GENERAL O & M
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-1-27



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

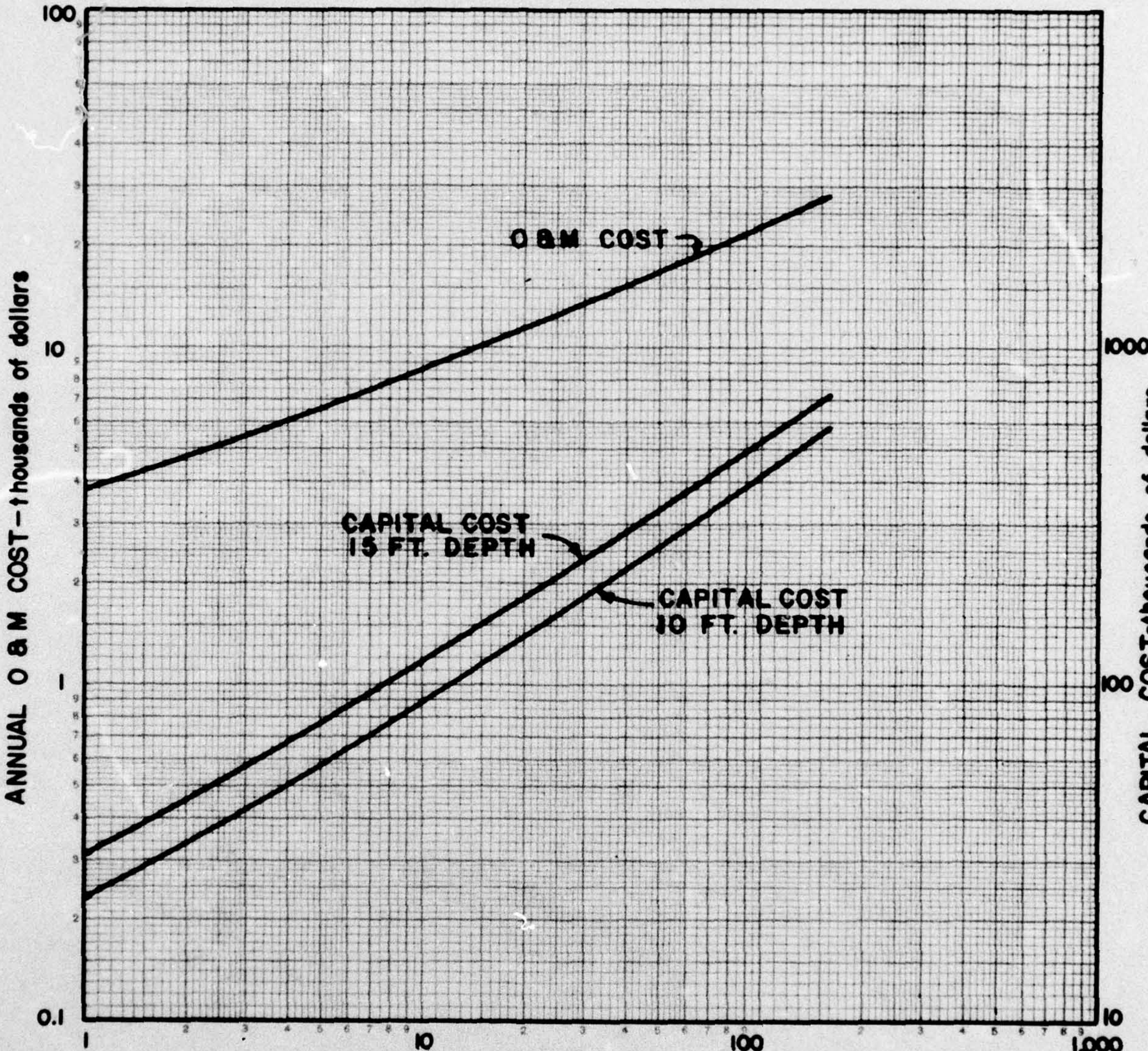
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

WASTEWATER STABILIZATION PONDS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-28

AERATED WASTEWATER STABILIZATION PONDS



POND SURFACE AREA-ACRES

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

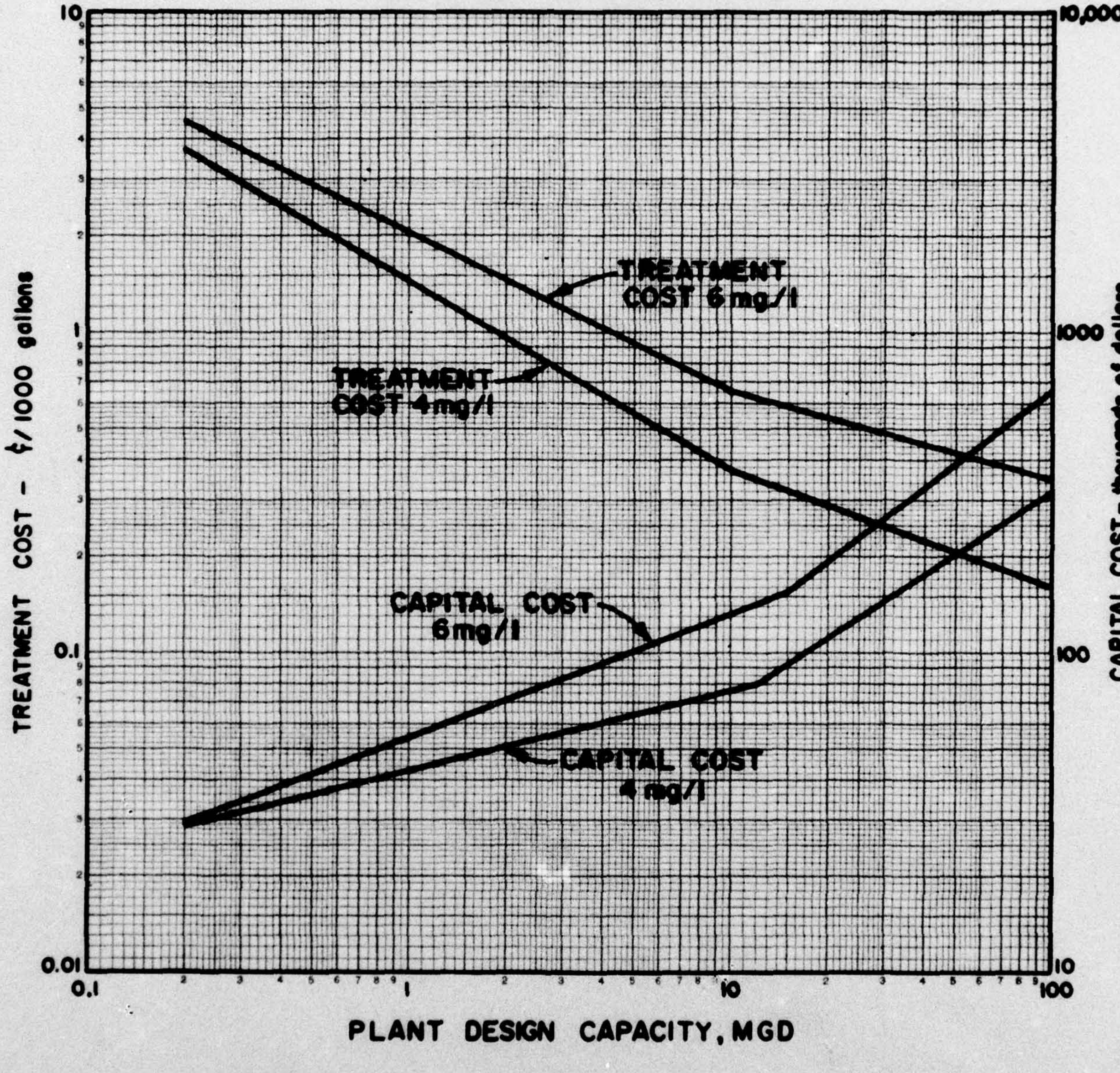
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

WASTEWATER STABILIZATION PONDS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

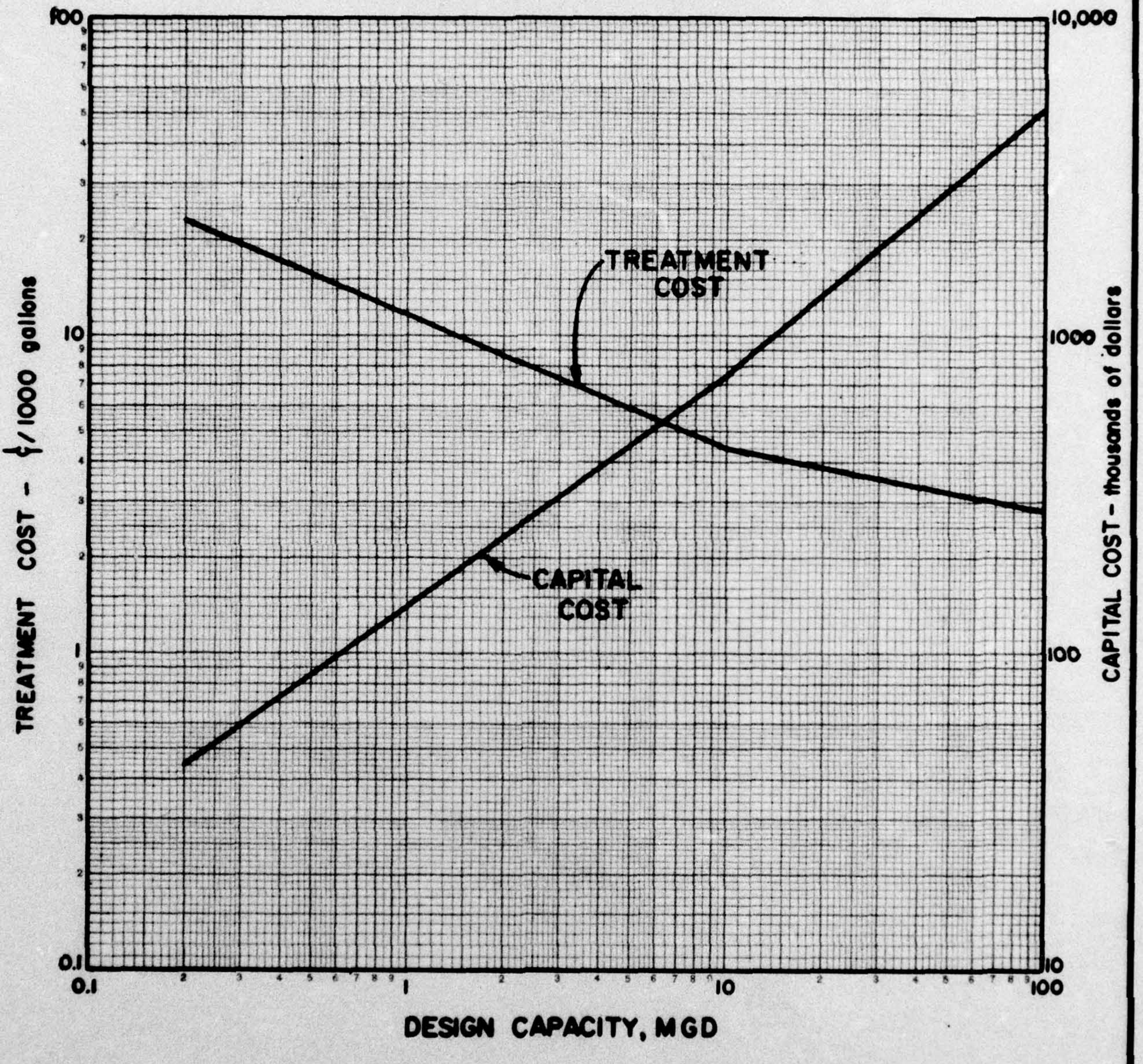
PLATE: TA-1-29

AERATION OF SECONDARY EFFLUENT
(FROM 1 MG/L TO 4 MG/L AND
1 MG/L TO 6 MG/L AT 20° C)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
TERTIARY TREATMENT COSTS
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-1-30

LIME CLARIFICATION
(TWO CLARIFIER PROCESS)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

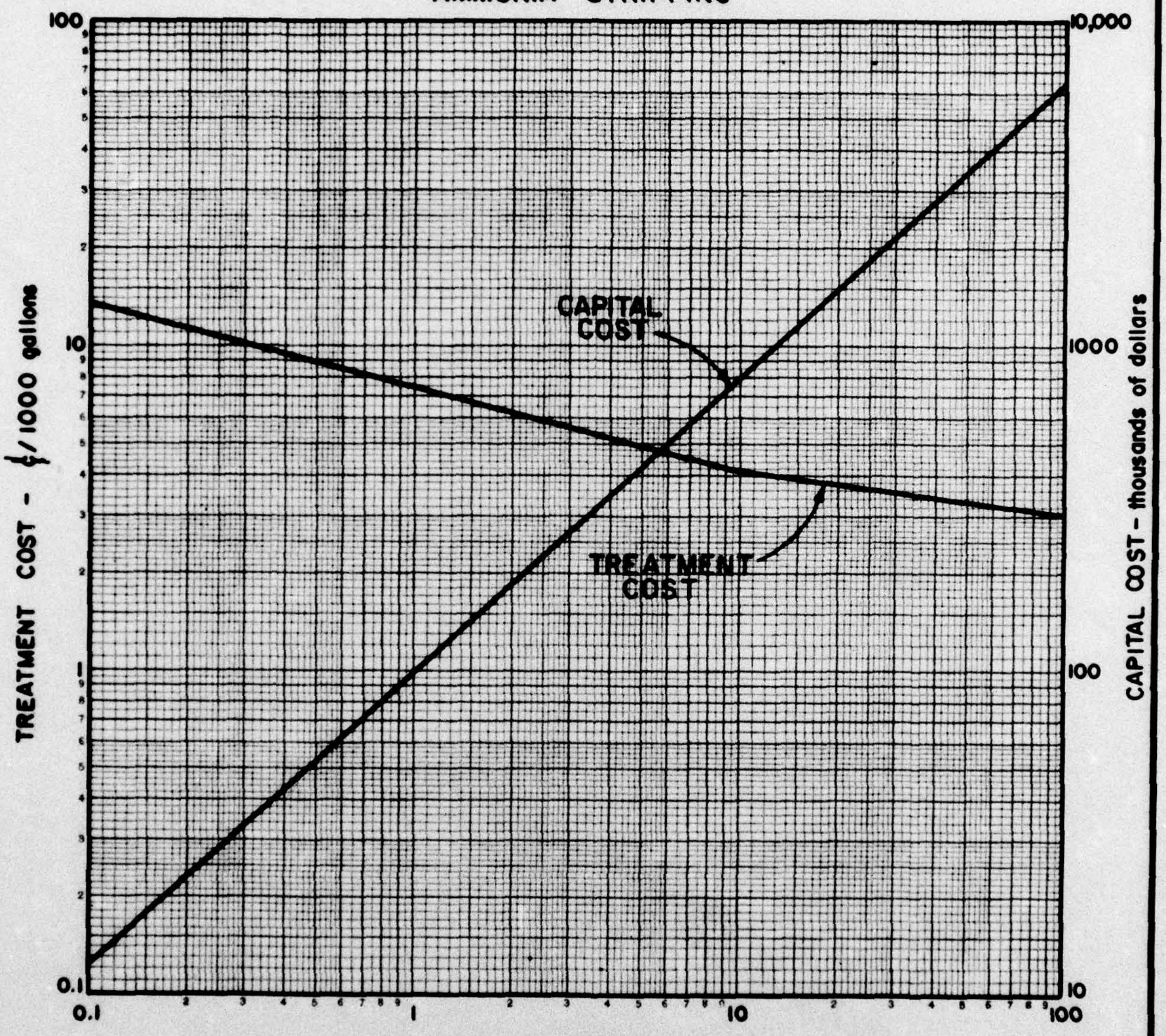
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-31

AMMONIA STRIPPING



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

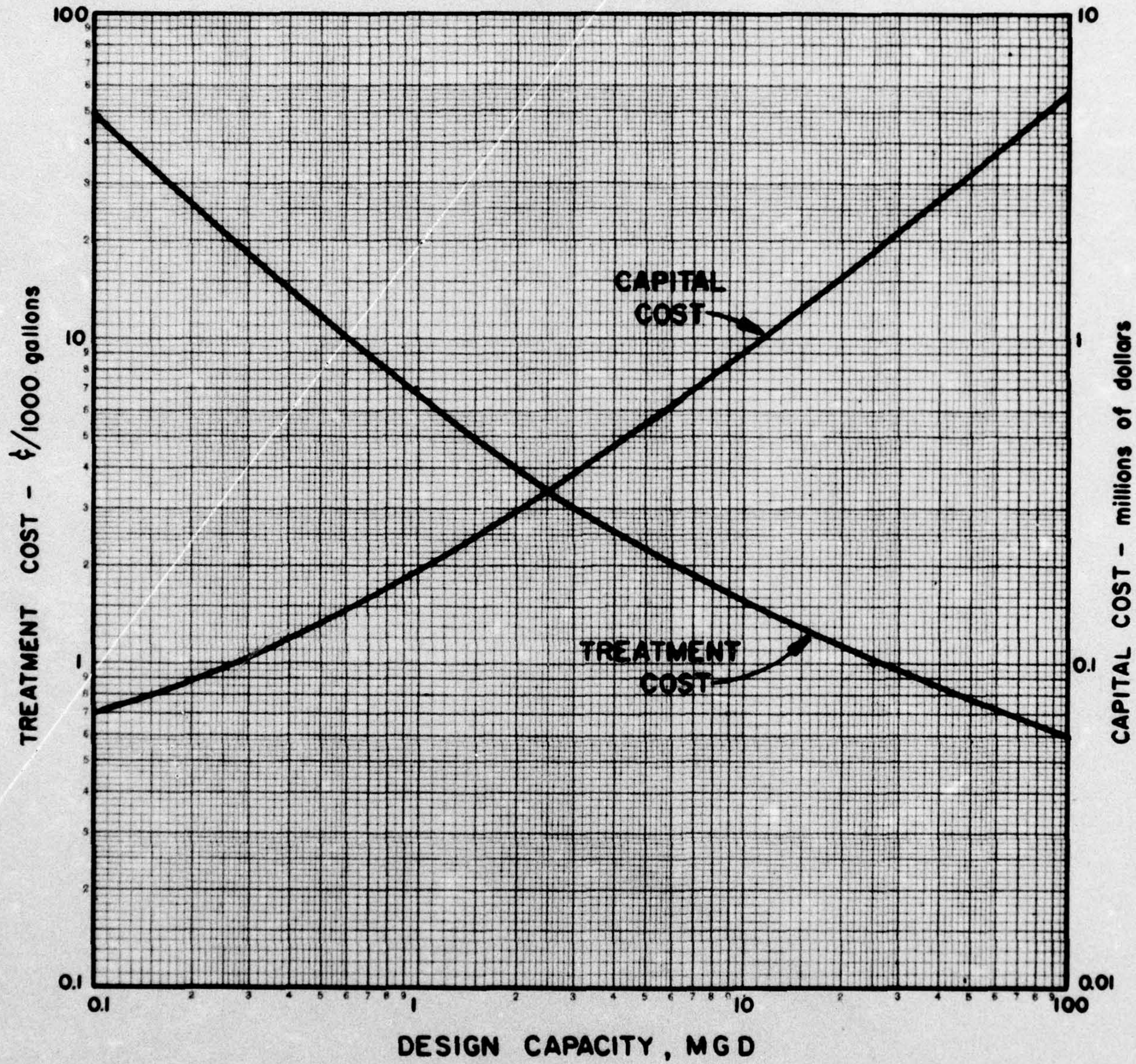
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-I-32

NITRIFICATION



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

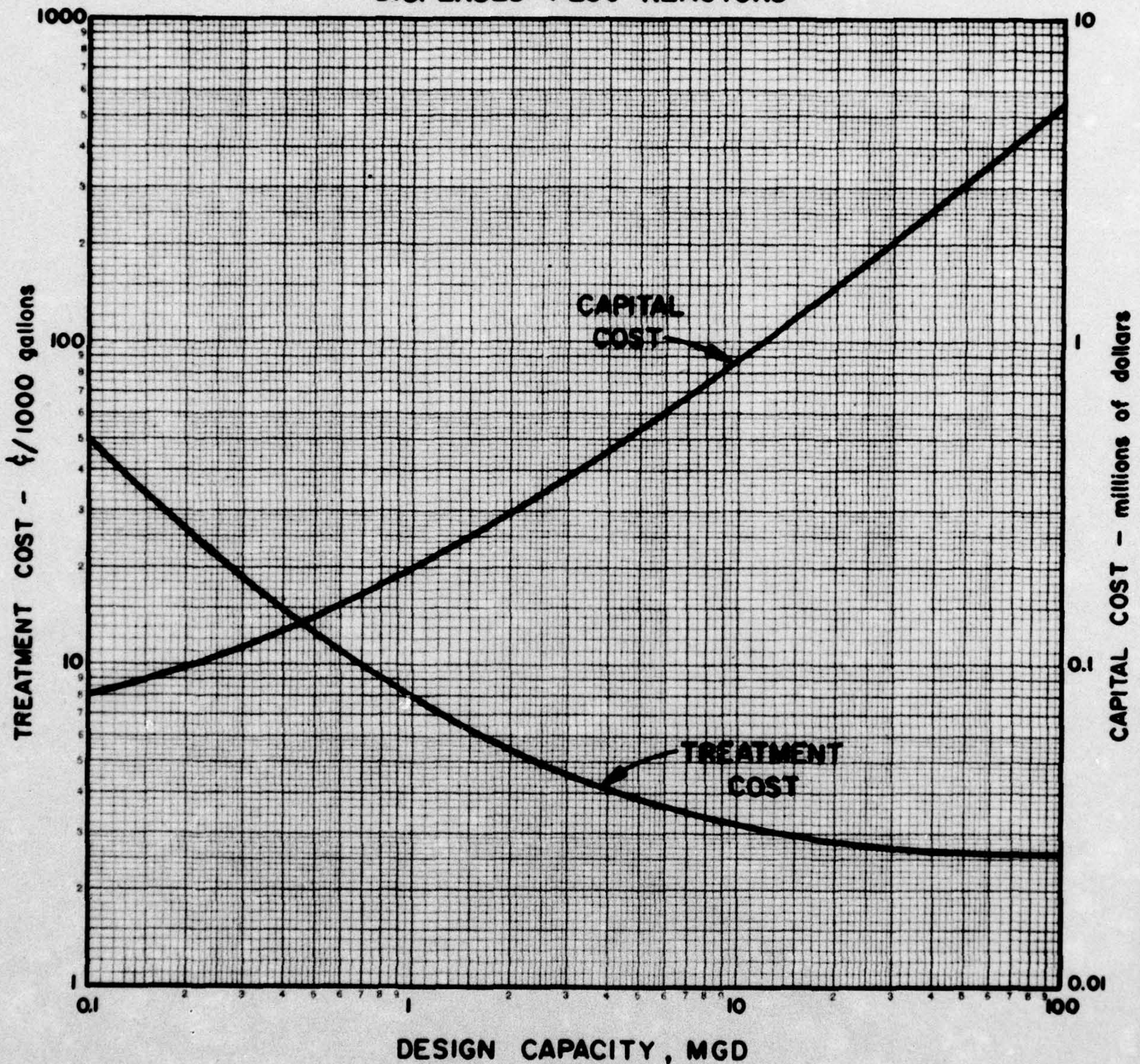
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-33

DENITRIFICATION IN DISPERSED FLOC REACTORS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

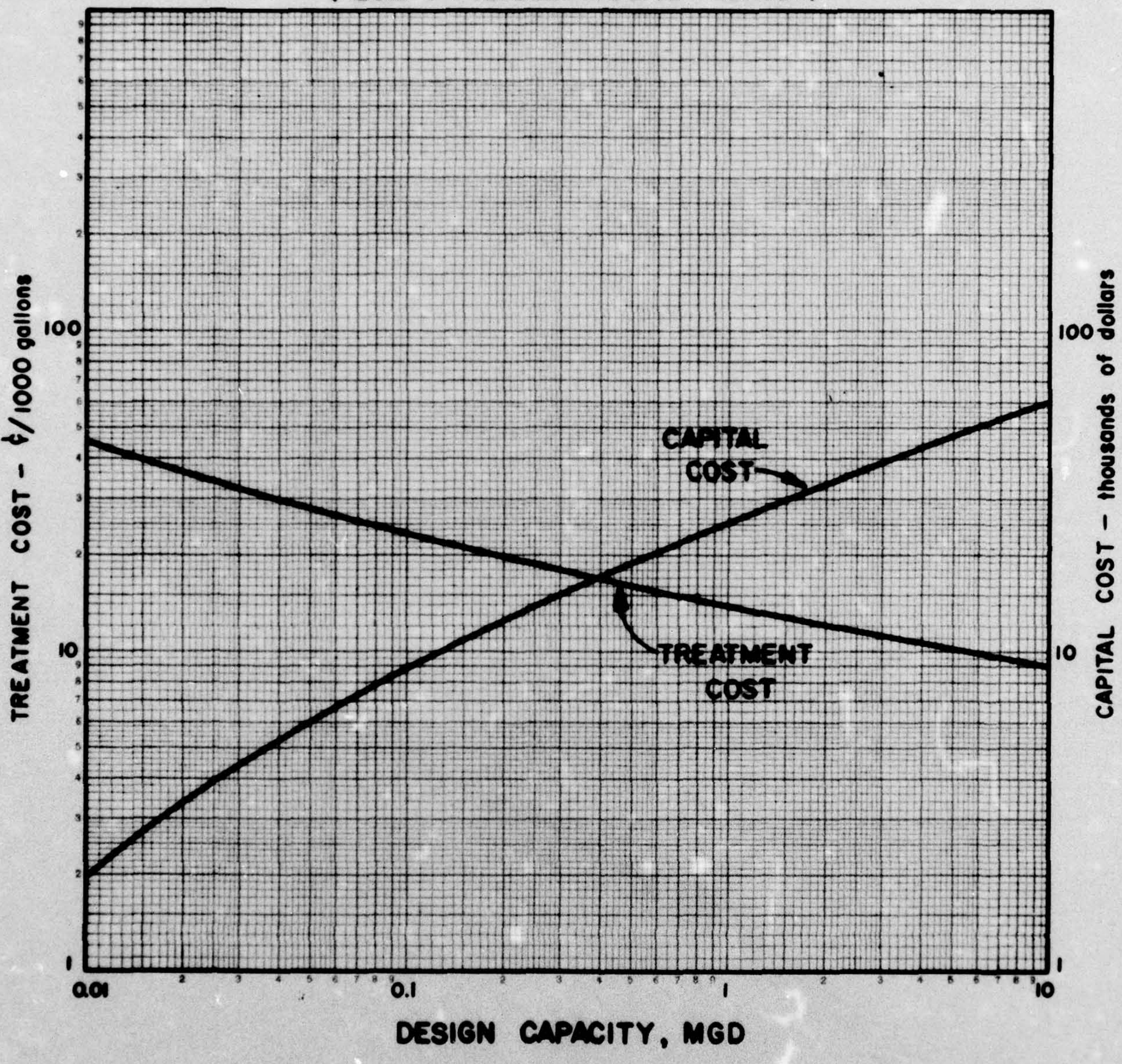
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-34

PHOSPHORUS REMOVAL
(ALUM + POLYELECTROLYTE ADDITION)



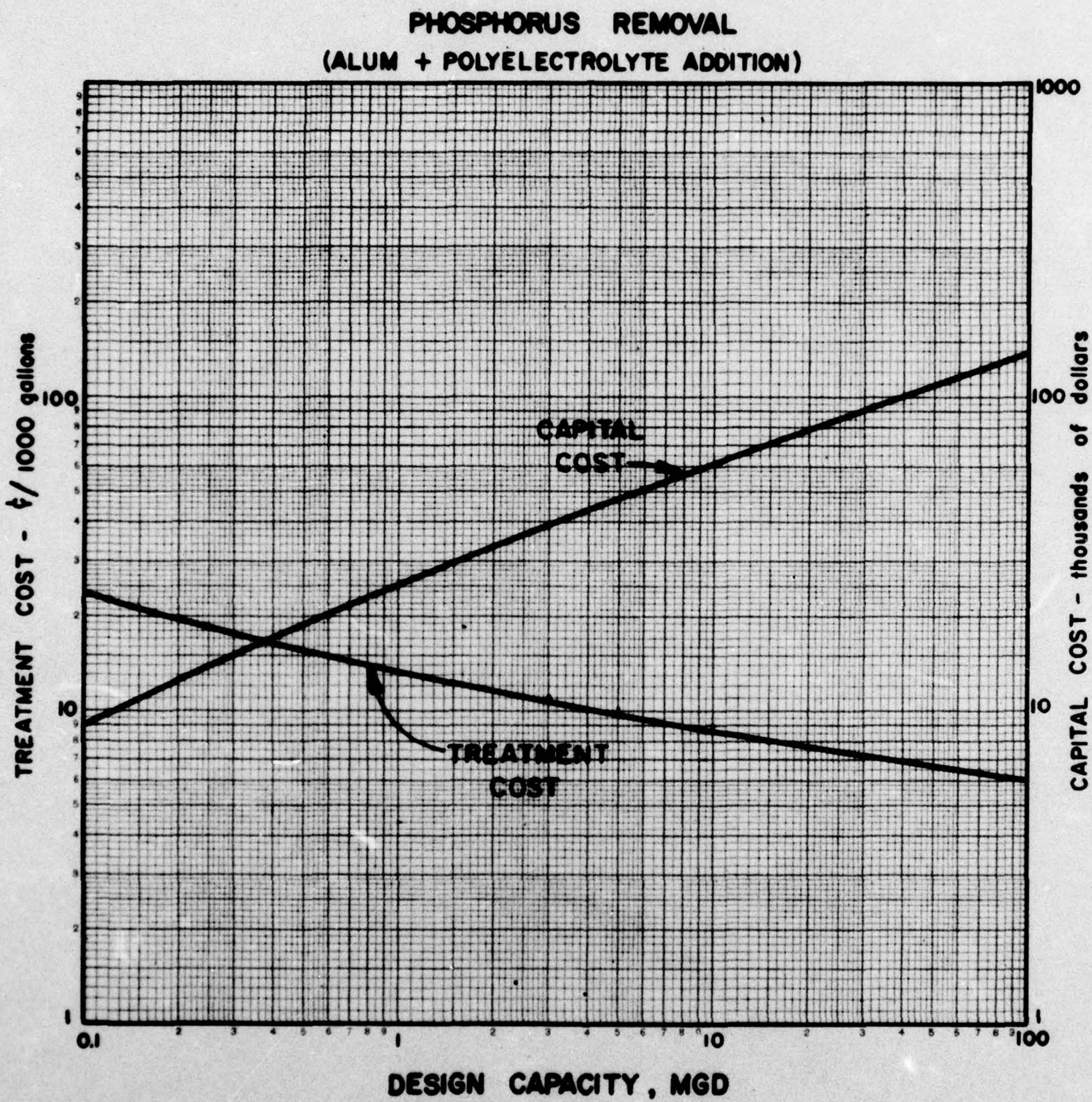
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT
COSTS

[illegible], COLLIE & [illegible], INC. [illegible]

PLATE: TA-1-39



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

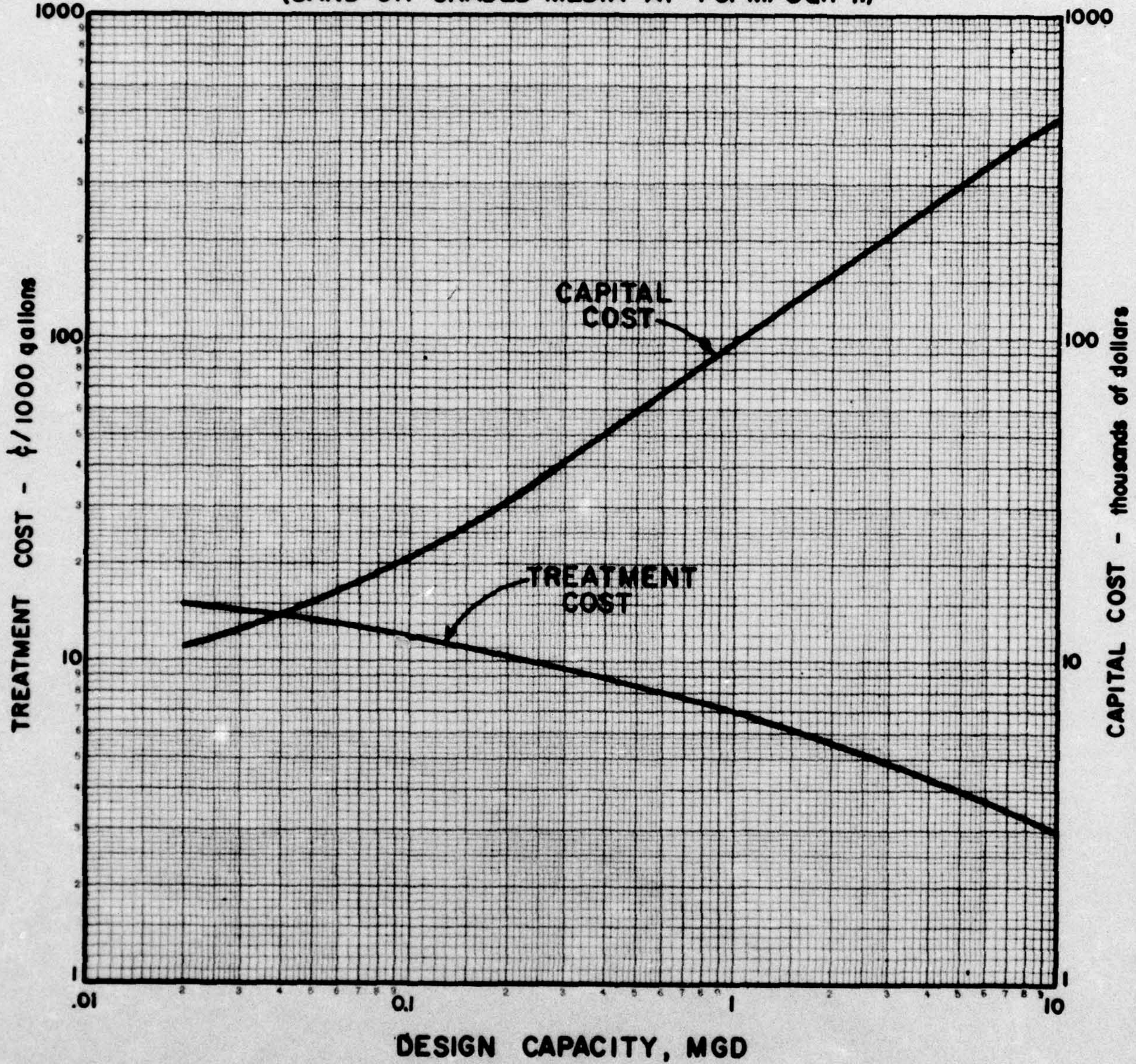
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-36

FILTRATION
(SAND OR GRADED MEDIA AT 4 GPM/SQ.FT.)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

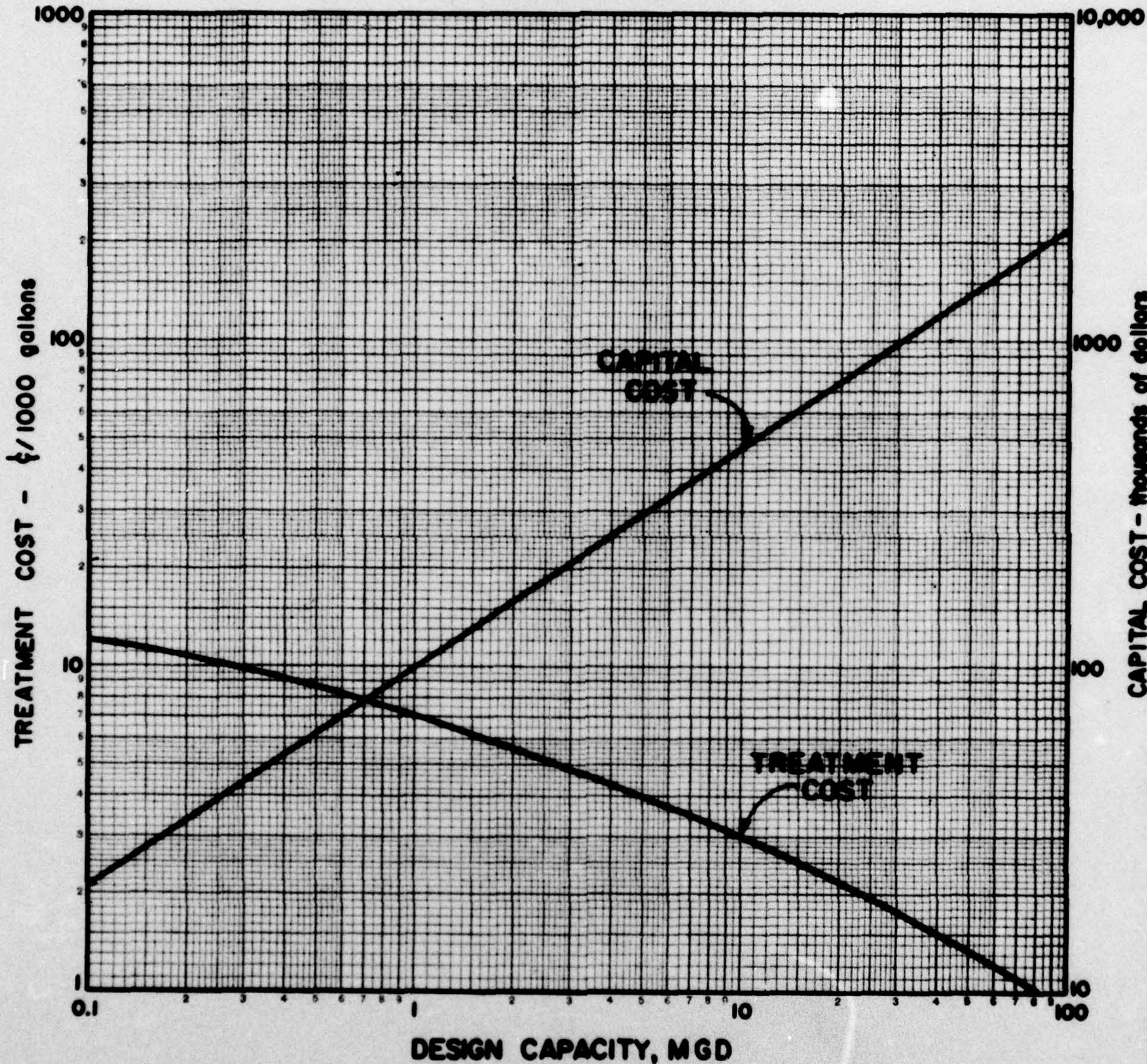
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT
COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: [illegible]-1-37

FILTRATION
(SAND OR GRADED MEDIA AT 4.0 GPM/SQ.FT.)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

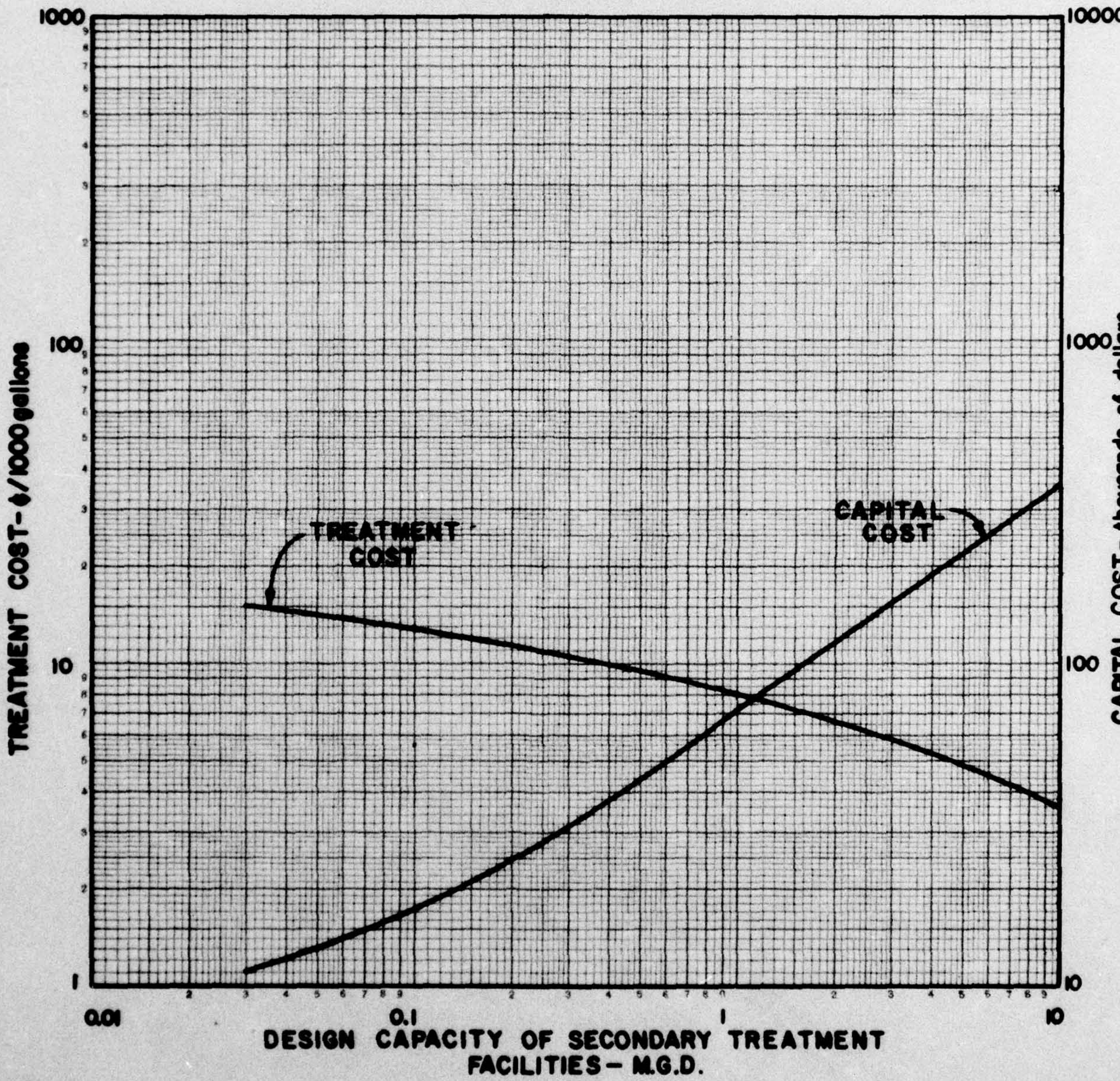
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

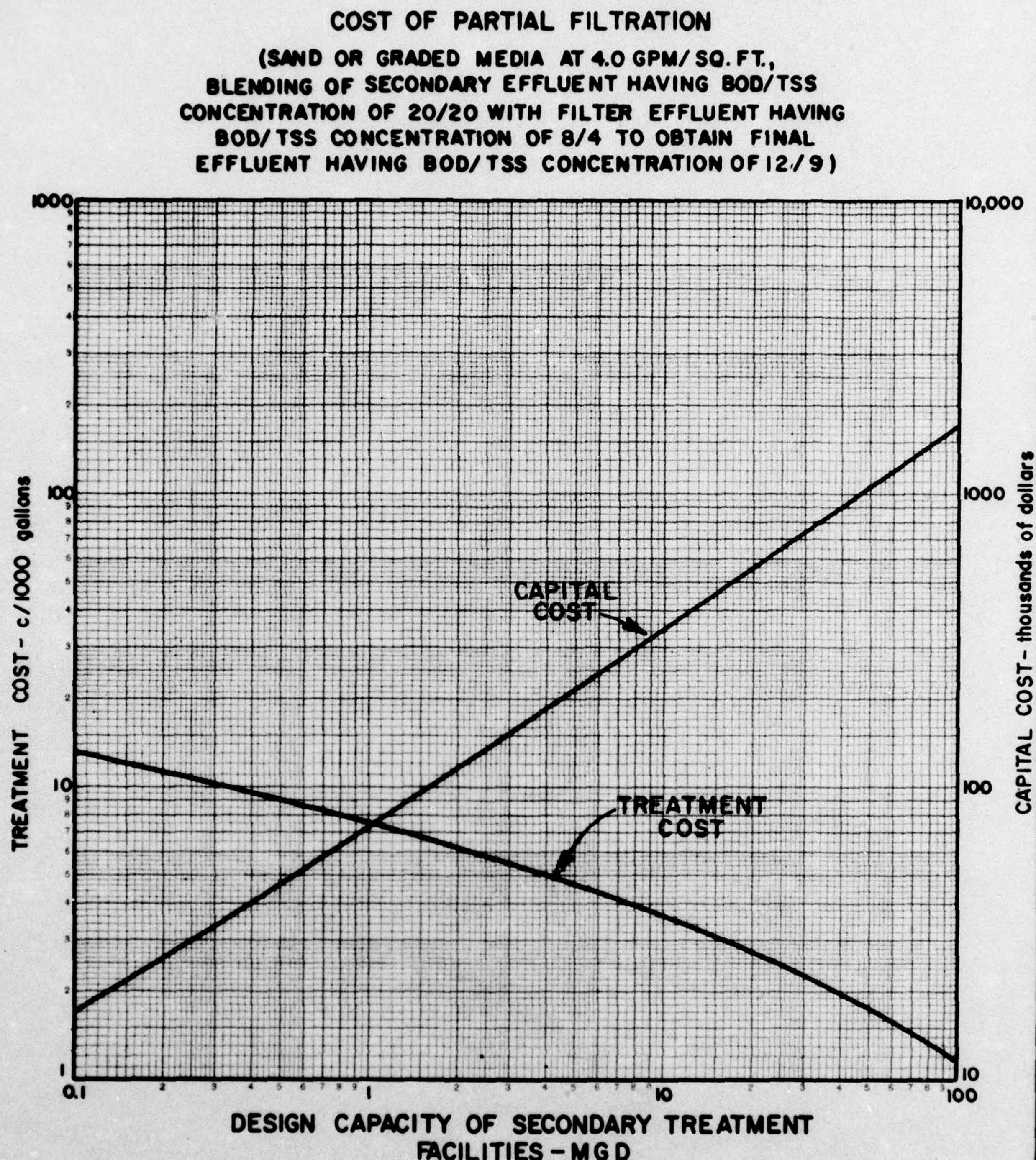
PLATE: YA-1-38

COST OF PARTIAL FILTRATION

(SAND OR GRADED MEDIA AT 4.0 GPM/SQ. FT., BLENDING OF SECONDARY EFFLUENT HAVING BOD/TSS CONCENTRATION OF 20/20 WITH FILTER EFFLUENT HAVING BOD/TSS CONCENTRATION OF 8/4 TO OBTAIN FINAL EFFLUENT HAVING BOD/TSS CONCENTRATION OF 12/9)



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
COST OF PARTIAL FILTRATION
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE: TA-I-39



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

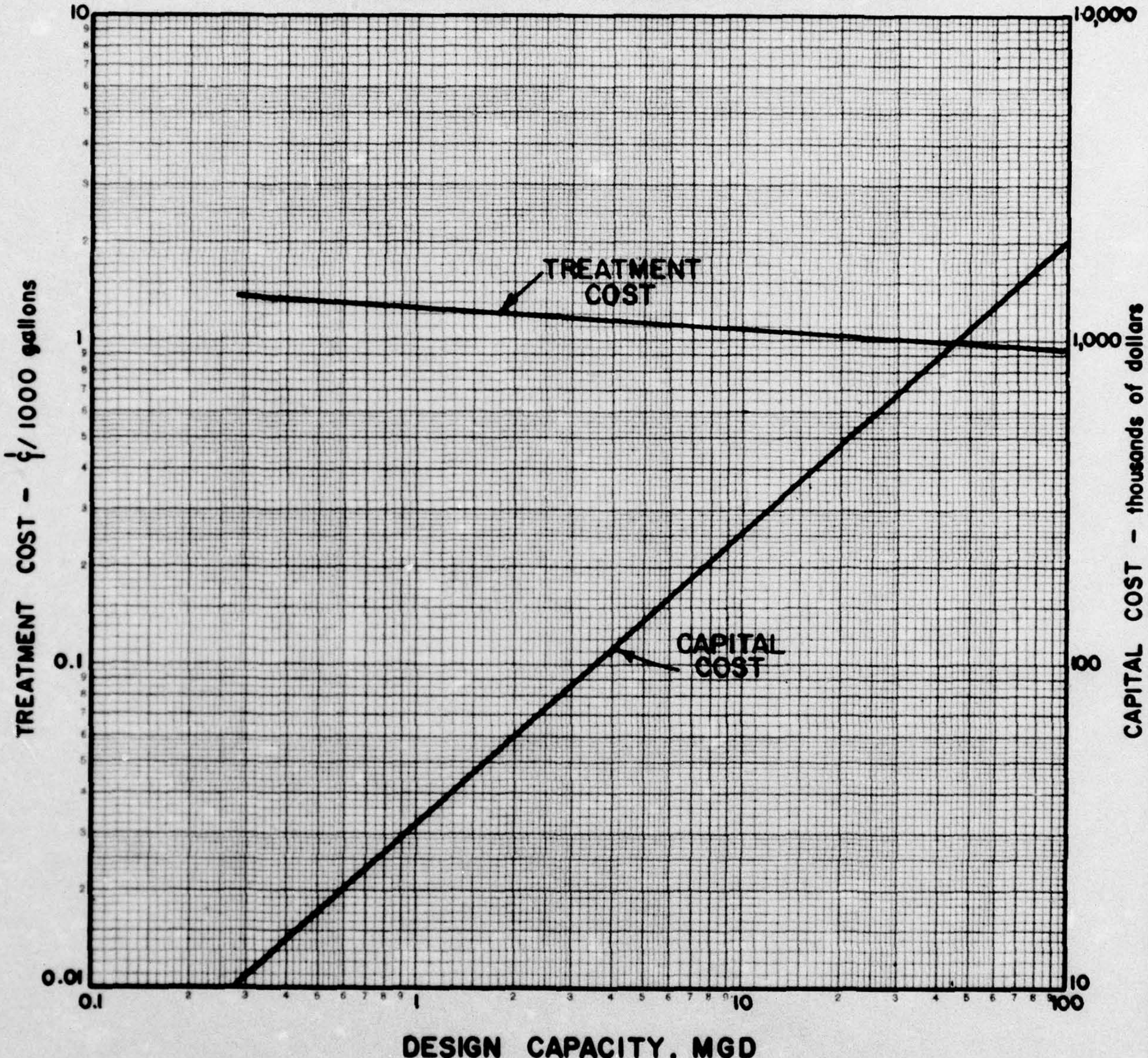
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

COST OF PARTIAL FILTRATION

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-40

MICROSCREENING OF SECONDARY EFFLUENT



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

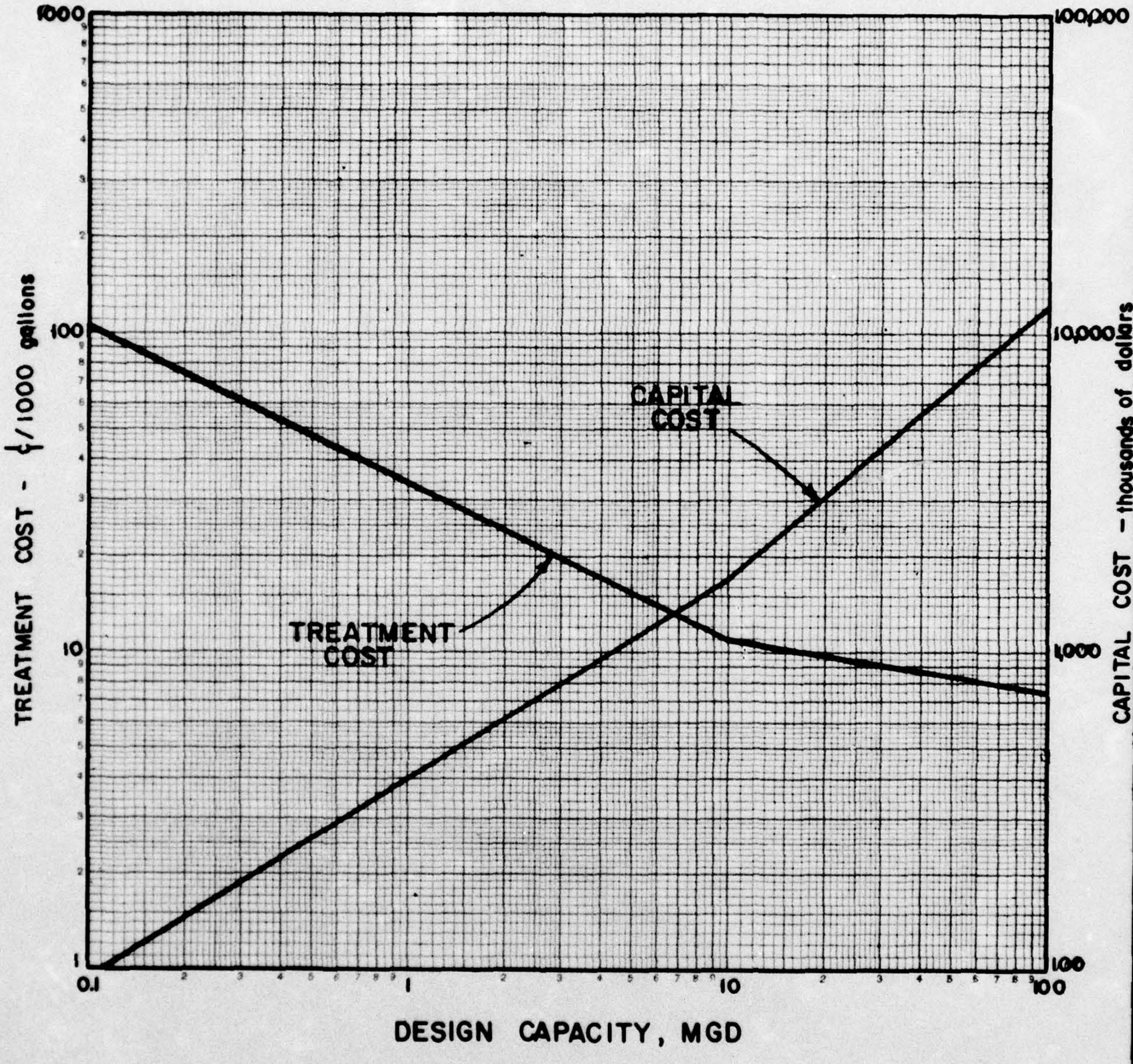
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT
COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-I-41

CARBON ADSORPTION



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

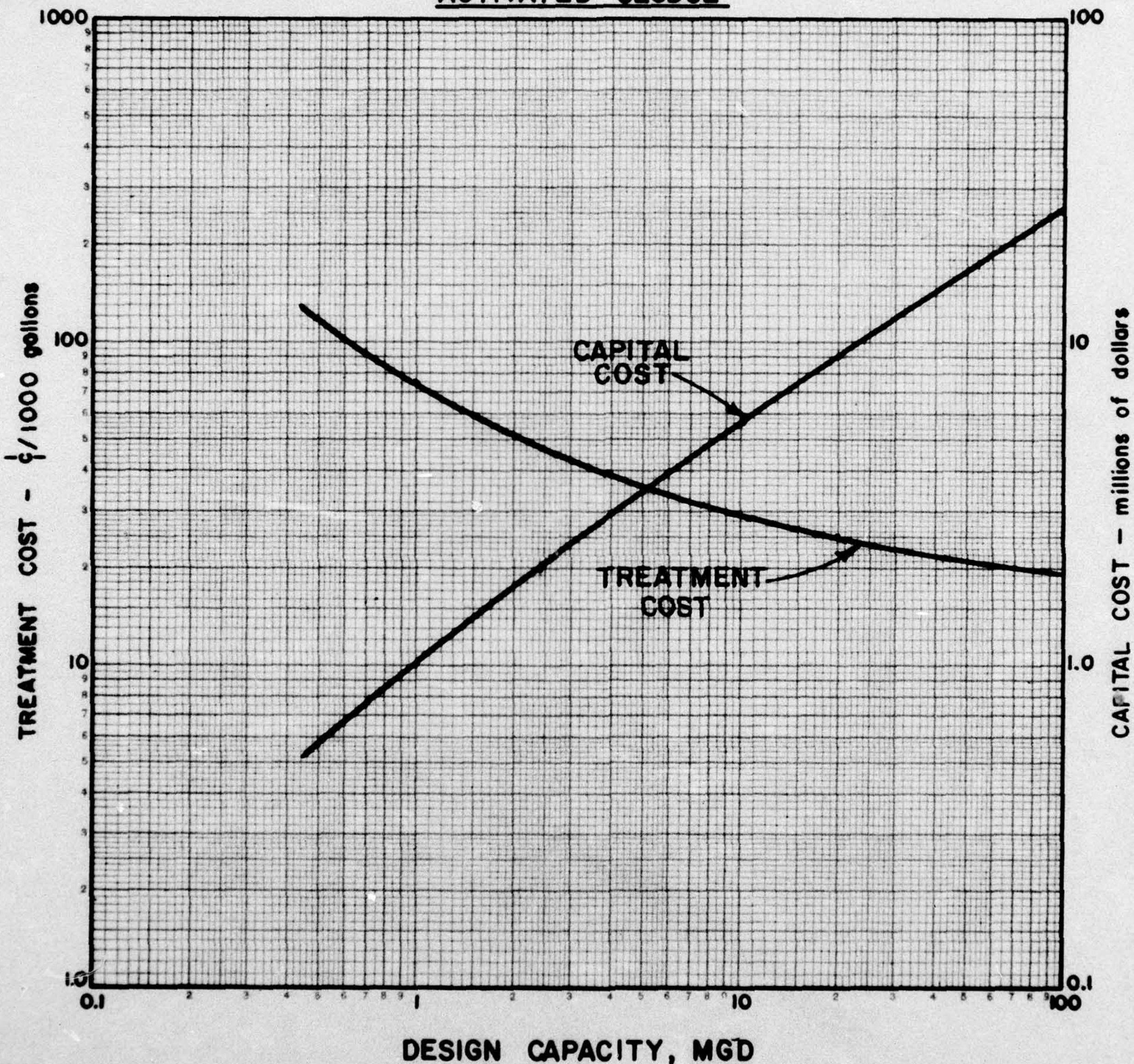
TERTIARY TREATMENT
COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA - 1 - 42

UPGRADING EXISTING FACILITIES

ACTIVATED SLUDGE



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

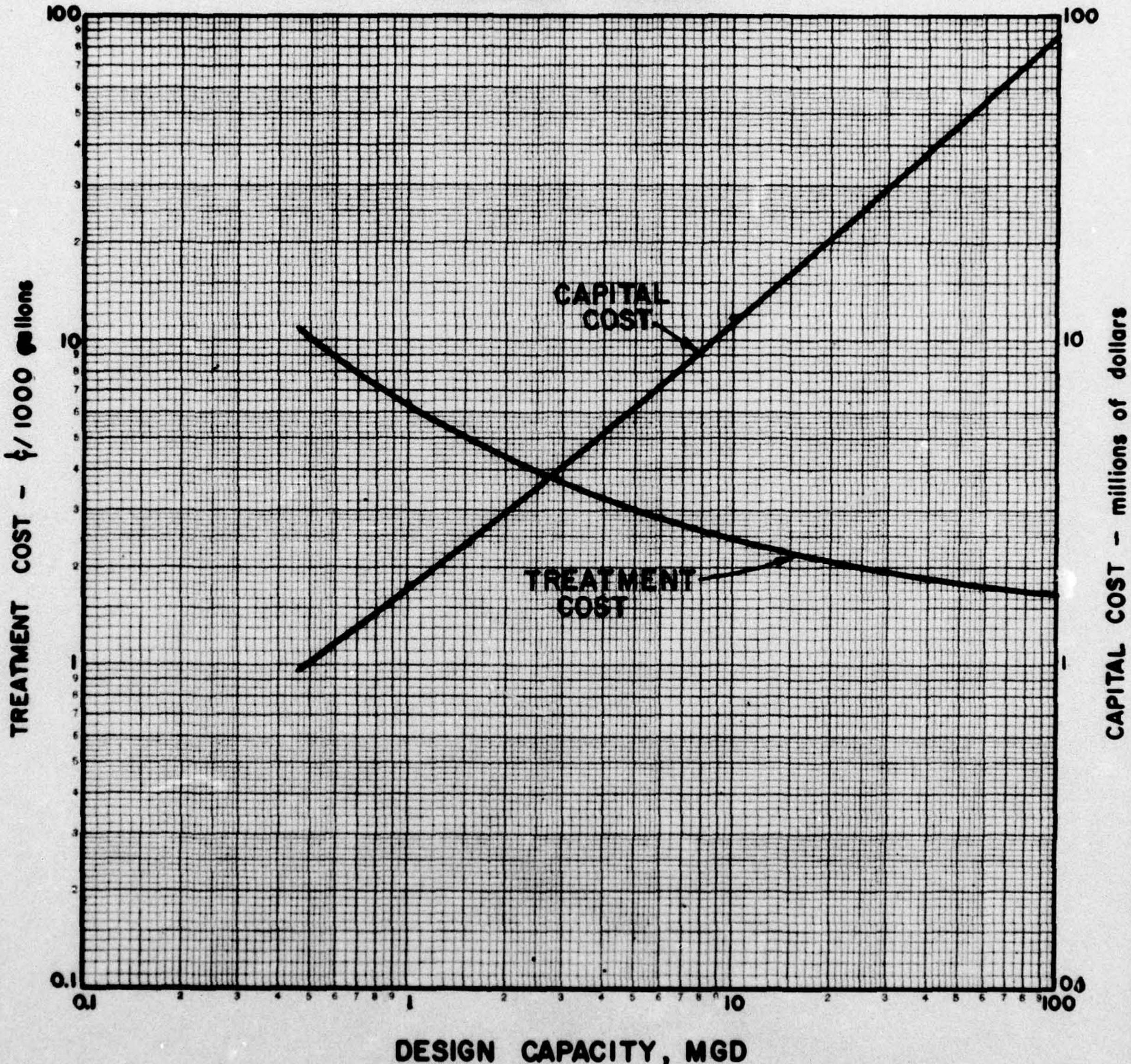
TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-43

UPGRADING EXISTING FACILITIES

TRICKLING FILTERS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

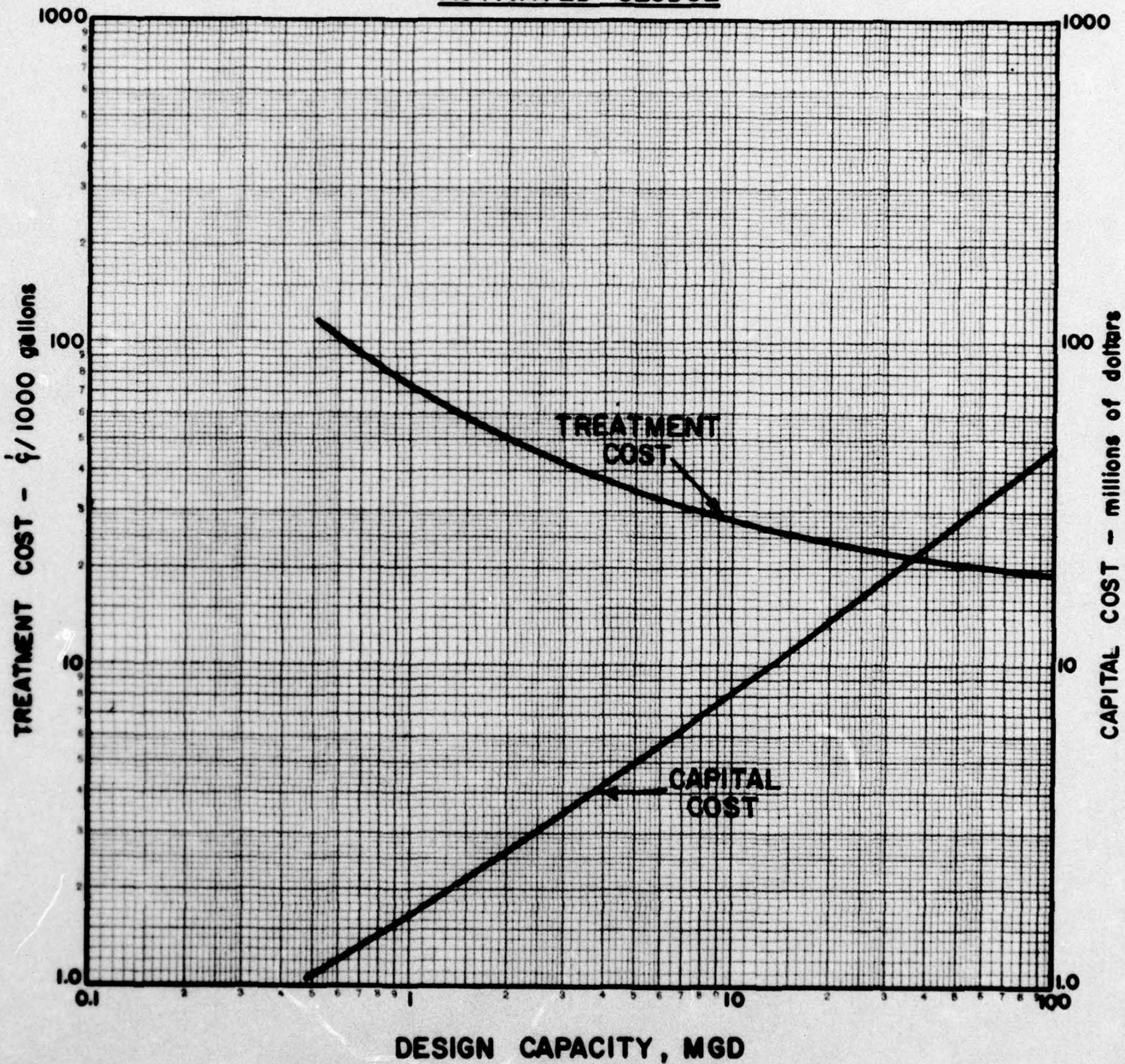
TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-44

BIOLOGICAL PROCESS TREATMENT OF RAW WASTEWATER

ACTIVATED SLUDGE



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

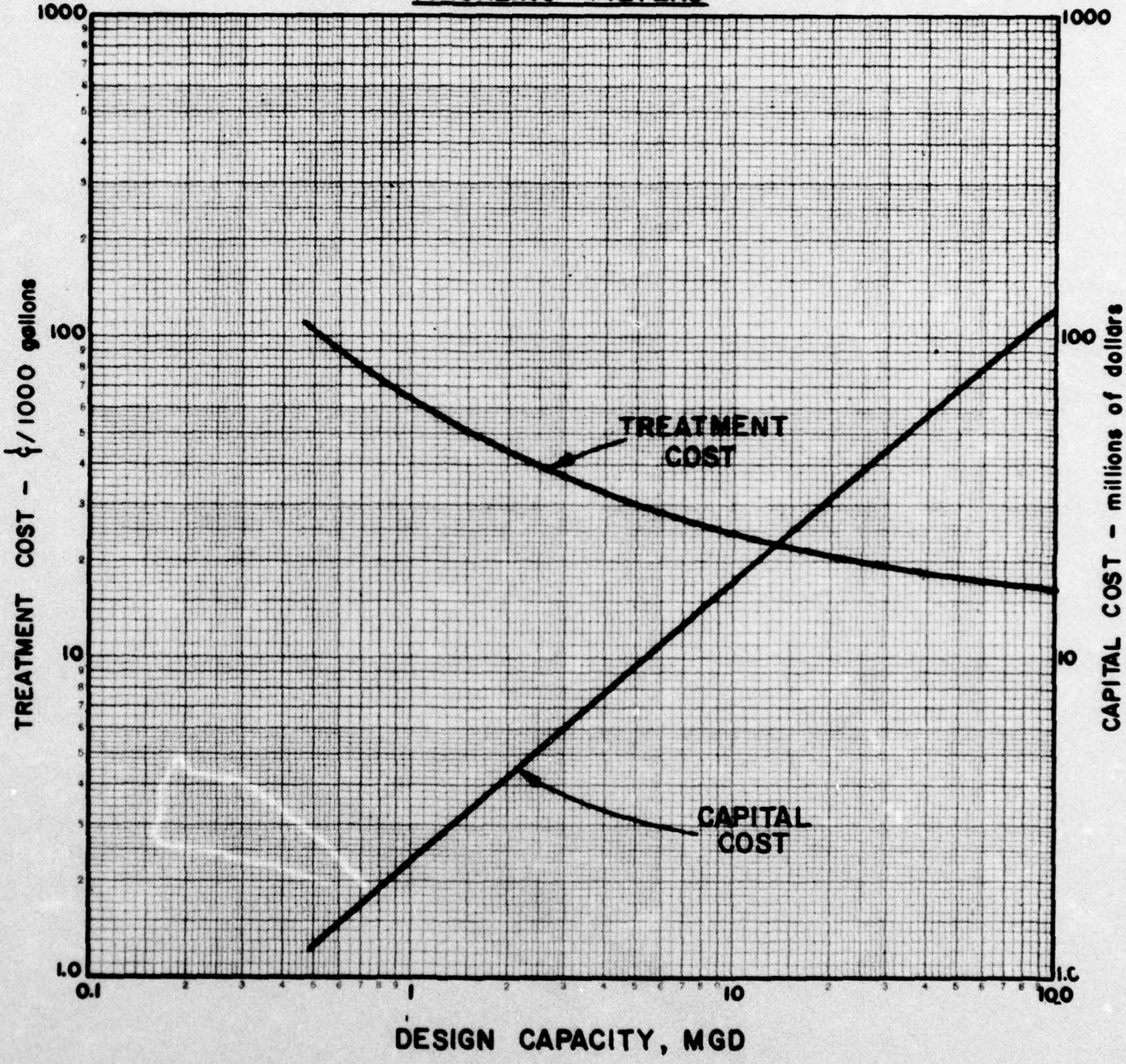
TERTIARY TREATMENT COSTS

[illegible]

PLATE: TA-1-45

BIOLOGICAL PROCESS TREATMENT OF RAW WASTEWATER

TRICKLING FILTERS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

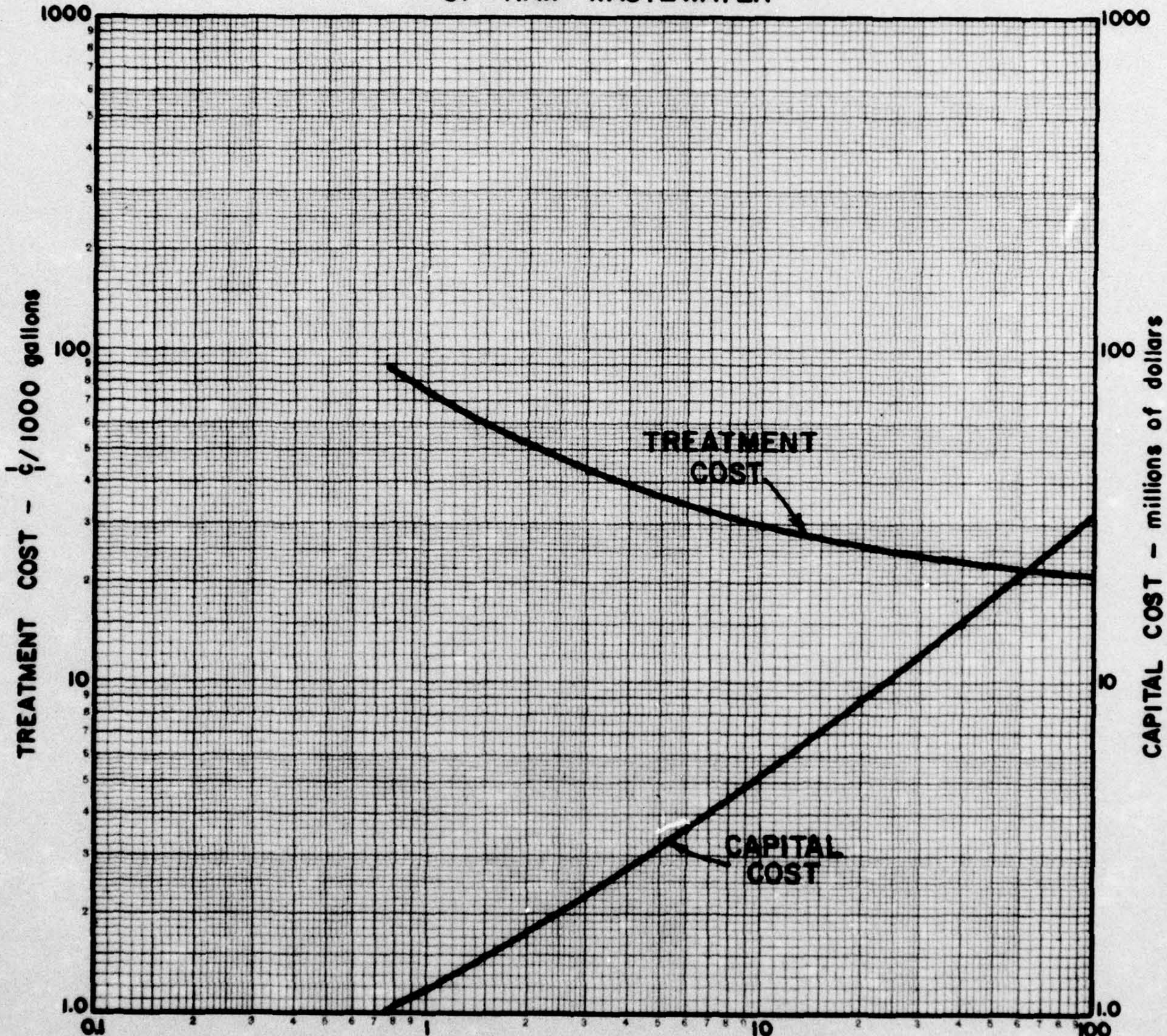
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-1-46

PHYSICAL - CHEMICAL TREATMENT OF RAW WASTEWATER



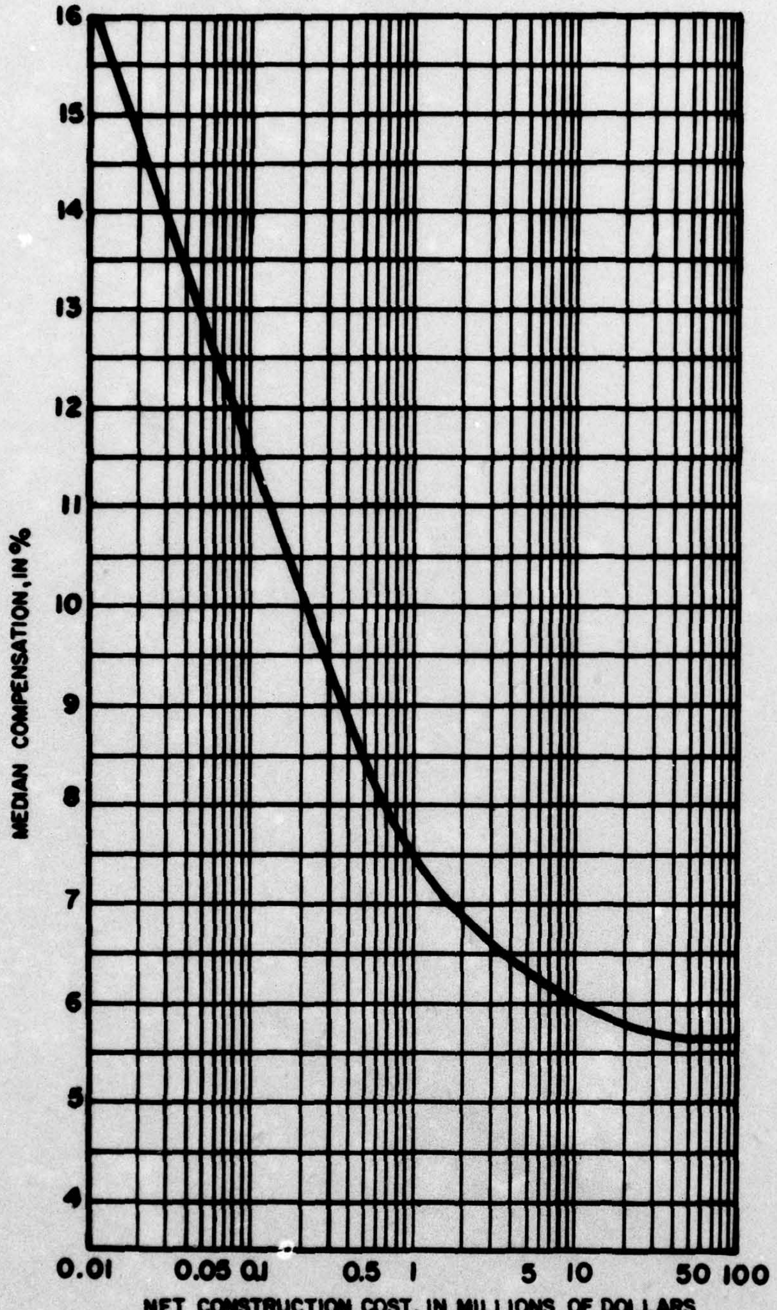
U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

TERTIARY TREATMENT COSTS

[illegible], COLLIE & [illegible], INC. [illegible]

PLATE: TA - 1 - 47



MEDIAN COMPENSATION FOR BASIC SERVICES EXPRESSED AS A PERCENTAGE OF CONSTRUCTION COST FOR PROJECTS OF ABOVE-AVERAGE COMPLEXITY (1971)

SOURCE: "CONSULTING ENGINEERING-A GUIDE FOR THE ENGAGEMENT OF ENGINEERING SERVICES", AMERICAN SOCIETY OF CIVIL ENGINEERS, 1972, MANUAL NO. 45, p. 28.

U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
ENGINEERING COSTS
[illegible]
PLATE TA-1-46

II. LAND DISPOSAL METHODOLOGY

The application of sewage effluent to land is not a new concept; however, it is becoming a subject of increased interest in the wastewater treatment field. Two major advantages to this practice are: (1) secondary effluent is an excellent source of irrigation water in areas where rainfall is not sufficient for maximum crop production, and (2) land disposal has been shown to be a superior form of advanced wastewater treatment, both in terms of economy and in providing a high degree of treatment.

The feasibility of land disposal as a technically viable alternative for wastewater management has been proven by a number of projects, including: (1) experiments at Penn State University, (2) a large land-disposal system which has operated in the vicinity of Melbourne, Australia for approximately 75 years, and (3) numerous smaller scale operations in the United States which use land to dispose of wastewater. A study by the Corps of Engineers for the Chicago metropolitan area demonstrated that a land-disposal system was competitive in terms of cost with either biological or physical-chemical systems which were all designed to achieve the same degree of treatment. Sewage irrigation in Texas has been practiced in Lubbock since the 1930's on the same land.

The renovation of wastewater applied to soils may be achieved by physical filtration, chemical combination, volatilization, ion exchange, biological reaction, and plant uptake. Physical properties of the soil important in renovation of wastewater are physical retention of water and sufficient aeration through the profile for final oxidation or chemical reaction.

Clay soils, unless very well structured, are poorly aerated and have low infiltration and percolation rates. However, since the reactive surface area of a soil is a function of the size of the particles, cation exchange capacity is a direct function of clay contents. Silt soils have greatly reduced reactive surface area, but improved properties for transmission of water and air. Sandy textured soils are usually classified as fine sands, coarse sands, and gravels. An ideal soil for land disposal would have a maximum reactive surface area and an adequate percolation rate with sufficient aeration. These conditions may be achieved in silt textured soils with a small percentage of clay but sufficiently high in organic matter to have well aggregated structure.

The three basic techniques of land disposal-spray irrigation, overland runoff, and rapid infiltration would each utilize combinations of the above renovative methods.

The selection of a land-disposal technique is not based only on site conditions but also on wastewater characteristics and water quality goals.

Wastewater Characteristics

For this report, the wastewater being considered for land disposal is assumed to be secondary treated municipal wastewater which may also contain some industrial wastewater. There is no exact definition as to the qualitative content of municipal effluent due to the many variables, such as the operation efficiency of the treatment system, seasonal and climatic conditions, and characteristics of the community served, including the presence or absence of any number of different industrial wastes in the municipal system. The secondary effluent characteristics also vary, depending on the type of biological treatment process used (i. e. activated sludge or trickling filter).

The list of typical secondary effluent characteristics given in Table II-1 was reported in the CRREL Special Report 171 "Wastewater Management by Disposal on the Land," May 1972 and is in general agreement with other such data in the literature.

The assumption that secondary level treatment will precede land disposal is based on several factors. First, most of the systems being considered for this alternate already have some form of secondary treatment. Second, there is a reduced risk of clogging of the soil at the site which results in noxious anaerobic odors as one drawback. Third, if land disposal cannot function on a year-round basis, storage must be provided which requires secondary level treatment for the maintenance of desirable conditions in the holding ponds.

The major area of concern in land disposal, assuming all other conditions are satisfactory, is that water quality goals may be impaired during the wintertime. If the ground is frozen, the infiltration capacity is reduced, which leads to ponding and/or runoff. Also, the metabolic rate of plants, microorganisms, and other life forms are reduced at low temperatures. As a result, the renovative capacity of the site is reduced. This problem is especially critical in the case of nitrates, the removal of which is entirely dependent upon the plants and microorganisms.

TABLE II-1

CRREL EFFLUENT CHARACTERISTICS

(All as mg/liter unless otherwise noted.)

I. Oxygen-demanding compounds		
a. BOD	25	
b. COD	70	
II. Biostimulants		
a. Nitrogen		Total N 20
		Organic 2.0 (as N)
		$+NH_4$ 9.8 "
		$-NO_2$ 0.0 "
		$-NO_3$ 8.2 "
b. Phosphorus		Total P 10
III. Other organic compounds		
a. Phenols	0.3	
b. Chlorinated and other complex organics – (Concentrations vary. Total concentration of these refractory organics approaches 45 mg/liter as indicated by the difference between COD-BOD results above.)		
IV. Inorganic compounds		
a. Metals		
Cadmium	0.1	
Chromium	0.2	
Copper	0.1	
Iron	0.1	
Lead	0.1	
Manganese	0.2	
Mercury	5 ppb.	
Nickel	0.2	
Zinc	0.2	
Sodium	S.A.R. = 4.6	
b. Non metals		
Boron	0.7	
Chlorides	100	
Sulfate	125	
V. Other characteristics		
a. Suspended solids	25	
b. pH	7.0	

Further restrictions are necessary even during summer months, since spray irrigation should be discontinued during periods of high winds and intensive rainfall.

Water Quality Goals

Water quality goals must be defined prior to any selection or discussion of a land-disposal technique. Specific water quality goals may vary in different locations. In some cases, direct reuse of wastewater may be desirable, while in others the avoidance of deleterious impacts on the receiving waters may govern.

It has been reported that, in general, the product water from land-disposal operations should approach drinking water - irrigation water standards in quality. This would seem to be a practical goal which would permit reuse and minimize any undesirable impacts on receiving waters. Presented elsewhere in the Appendix are a number of water-usage requirements determined for this study. A summary of the drinking water and farmstead standards is present in Table II-2, with the more severe limitation of a parameter being listed where there was a difference in standards.

Nitrogen and phosphorus must be considered separately under water quality goals. These are an agricultural benefit and therefore not limited by irrigation standards. Only the nitrate form of nitrogen appears in drinking water standards since it can cause methemoglobinemia in certain concentrations. However, both nitrogen and phosphorus are identified as the major causative agents in eutrophication of natural waters. In summary, defining the water quality goals for nitrogen and phosphorus depends upon the intended use of the product water from land disposal. If reuse for industrial or agricultural purposes is intended, the removal of these elements may not be critical. For recharge of natural ground water, the nitrate limitation must be satisfied. If discharge into lakes or ponds is intended, then both nitrogen and phosphorus control is necessary.

A reasonable goal for nitrogen seems to be a maximum of 2 mg/l and for phosphorus a maximum of 0.02 mg/l, using spray irrigation.

TABLE II-2

WATER STANDARDS SUMMARY

Substance	Drinking water (mg/liter)	Farmstead water (mg/liter)	Controlling concentration (mg/liter)
BOD	1*	–	1
COD	1*	–	1
$+NH_4$ (as N)	–	–	–
$-NO_2$ (as N)	–	–	–
$-NO_3$ (as N)	10	–	10
P	–	–	–
Phenols	0.001	–	0.001
Cadmium	0.01	0.005	0.005
Chromium	0.05	0.005	0.005
Copper	1.0	0.2	0.2
Iron	0.3	–	0.3
Lead	0.05	5.0	0.05
Manganese	0.05	2.0	0.05
Nickel	–	0.5	0.5
Zinc	5.0	5.0	5.0
Boron	–	0.75	0.75
Chlorides	250	–	250
Sulfates	250	–	250
Suspended solids	–†	–	5
Color	15	–	15
Taste	Unobjectionable	–	Unobjectionable
Odor	3	–	3
Turbidity	5	–	5
Aluminum	–	1.0	1.0
Beryllium	–	0.5	0.5
Selenium	0.01	0.05	0.01
Silver	0.05	–	0.05
Vanadium	–	10.0	10.0
Arsenic	0.05	1.0	0.05
Barium	1.0	–	1.0
Cyanides	0.2	–	0.2
Cobalt	–	0.2	0.2

*Carbon chloroform extract to measure organic contaminants.

†Suspended solids should approach turbidity requirements.

Site Conditions

The first characteristic of a site to receive consideration should be its ability to move the wastewater at the desired rate on a long-term basis. The three techniques of land disposal differ as to the volume and pathway of the wastewater applied. Both rapid infiltration and spray irrigation depend on the ability to move water vertically downward through the soil. Their suitability for a site depends on percolation capacity. Soils with high percolation rates may be considered for rapid infiltration, while those with low percolation rates may be considered for overland runoff.

Two other factors which should be considered are the surface infiltration capacity and the slope of the site.

In agricultural terms, any soil desirable for crop growth shows potential for either spray irrigation or overland runoff, depending on the slope and subsurface drainage characteristics. In the general case, the soil should be naturally adaptable to the intended application mode since extensive surface preparation probably would result in a prohibitive high cost. The exception to this consideration is that surface runoff both into and from the disposal site must be controlled. Natural runoff from adjacent lands may impair a site's renovative capacity, while uncontrolled runoff from a site may result in legal and practical problems. The need for recovery of product water from overland runoff is apparent to prevent intrusion on adjacent properties. The need for subsurface recovery at spray irrigation and rapid infiltration sites is more difficult to define. The system will probably consist of either a shallow underdrainage pipe network or deeper recovery wells. In either case, it would be desirable to recover only the volume of water applied to the site. If either method is installed below the natural water table, the subsequent drawdown should recover all applied water in addition to a significant amount of natural ground water.

Spray Irrigation

Spray irrigation is the controlled spraying of liquid onto the land, at a rate measured in inches per week, with the flow path being infiltration and percolation within the boundaries of the disposal site. Sites vary from perfectly flat to steeply sloping, the steeper sites being in forested areas where the natural forest litter on the ground surface controls erosion. Agricultural sites are either flat or, at most, have a gently

sloping topography to permit operation of farm machinery. Management practice for such sites is similar to conventional farming and depends on the type of crop selected.

The choice of crop depends upon location, on regulations covering sewage irrigation, and the use of the harvested crop. Many different crops have been used successfully in land disposal operations. Crops irrigated with sewage effluent in Texas include wheat, cotton, grain sorghum, alfalfa, rye, corn, oats, and pasture grasses which include Johnson grass, Coastal Bermuda grass, and Reed canary grass.

Corn and some of the grasses grown as hay crops seem to have more favorable renovative capabilities. Both demonstrate significant nutrient uptake and have potential market value after harvest. Corn may have a higher market value but it requires annual plowing and planting, where the perennial grasses require only harvest. The grasses have a further advantage in that their root systems are fully developed at the start of the spraying season. Reed canary grass has been used successfully at a variety of sites in the United States and seems to be a desirable species.

The total spray area required is directly dependent on the design application rate. Application rates throughout the country vary from 0.2 inches per acre per week to a maximum of 6.0 inches per acre per week. Based on a 7-year study at Penn State, 2 inches per acre per week seems to be desirable for both forest and agricultural applications. The number of possible combinations is infinite, but the average of 2 inches per acre per week at a spray rate of 0.25 inches per hour is suggested as a conservative base for planning. An 8-hour spraying period during the normal working day would then apply the whole 2 inches in one day with a 6-day rest period.

The available renovative soil depth at a spray irrigation site will depend on the local ground water control measures used. The maximum possible depth would be desirable to ensure reserve capacity for retention of phosphorus and other inorganics. If the natural ground water table is fairly deep and has sufficient horizontal permeability to allow lateral movement of the renovated wastewater, there would be no need for an underdrainage system. However, since these factors can only be determined by an extensive field investigation, it would be conservative to assume for planning purposes that ground water control may be required at all sites. Recommendations in the literature vary from 5 to 10 feet

from ground surface to ground water to avoid contamination. For fine textured soils, a depth of 5 feet should be adequate for renovation and removal of pathogens.

Spray irrigation is a versatile means of applying water to the surface of any soil. This method of land disposal utilizes a sprinkler system which can apply water to soils at rates equal to, greater than, or less than the infiltration rate. The systems can be completely automatic or manually operated.

There are many types of sprinklers but all may be grouped into three general classes according to portability: (1) portable sprinkler systems, (2) semi-portable systems, and (3) stationary systems. The portable and semi-portable systems are most commonly used in agriculture. A fully-portable system consists of either a stationary or portable pump and portable main lines, laterals, and sprinklers. The semi-portable system usually consists of a stationary pump and stationary main pipelines with portable laterals. Stationary systems are those in which the main pipelines, laterals, and sprinklers are fixed permanently throughout the entire area to be irrigated.

Portable and semi-portable systems can also be classified according to the method of moving the laterals. A common method is the hand-moved system in which the laterals are moved by hand. There are also various types of power moveable systems designed to reduce the labor cost of moving pipe. In the side-roll lateral system, the lateral pipe acts as the axle of large diameter wheels. A small gasoline engine mounted at the midpoint of the line is used to roll the lateral to the next position. There are also various types of end-pull systems in which laterals are moved to the next position by pulling one end with a tractor or other power unit. The side-roll systems are limited in application to crops which will not interfere with movement of the pipe. The hose-pull system employs buried mains and submains and a large number of small diameter flexible hoses upon which one or more sprinklers are mounted. The labor requirement involves pulling the hoses manually to the next sprinkler position. The skill of the labor is minimal, and the system need not be shut off to move sprinklers.

Boom-type sprinkler systems employ only one boom sprinkler on each lateral. The boom is a nozzled, slowly rotating pipeline which is suspended from a portable tower. Boom sprinklers are generally moved by towing the towers to the next position along the laterals with a tractor

or winch. These large sprinklers irrigate widths of 250 to 350 feet, which is generally undesirable for irrigation with sewage effluent due to the greater possibility of wind carrying the spray from the disposal site and the high evaporative losses. A common self-propelled sprinkler system consists of a radial pipeline supported at a height of 6 to 8 feet at intervals of about 100 feet. The radial line is rotated slowly around a pivot point in the center by either water pressure or electric motors. However, this type of equipment is being used extensively in the larger land-disposal operations, such as those in the Muskegon, Michigan area, to minimize the number of irrigation units required.

Stationary systems are more frequently used for sprinkling lawns and turfs, and high value crops. They are more expensive in initial cost than other systems, but labor and operational costs are minimized. Another advantage is that the efficiency of water application to crops is higher, since a more controlled application with respect to volume of water and area covered is possible.

In designing systems for use by municipalities for the purpose of cost estimating, a 6 to 8-hour application period was assumed so that city employees may operate the system during a standard working day. An application rate of once every seven days was assumed to allow the soil to dry and aerate without becoming saturated.

In areas proposed for spray irrigation where the water table must be lowered for efficient and safe operation, subsurface drains will probably be used. These drains are generally constructed of clay or concrete pipe in 2 to 4-foot lengths with a 1-1/8-inch space between each joint to allow ground water to enter the pipe. A gravel envelope is placed about the pipe to stabilize the base material and provide a permeable path for water to move into the open joints. The Bureau of Reclamation is presently installing and evaluating test reaches of corrugated, perforated, polyethylene drainage tubing. The major advantages of the plastic drain pipe are that it is easier to bury and it is cheaper.

The spacing of the drains is influenced by the texture and permeability of the soil. In clay soils of low permeability, close spacing of 200 feet may be essential to satisfactory drainage; in average loam soils, 400 to 600 feet is good spacing; in sandy and gravelly soils, spacing at 800 feet or more is general practice.

For the purpose of cost estimating, several spacings were assumed for different land area requirements. A cost of $22,000 per mile of pipe was then applied, which was furnished by the Bureau of Reclamation. The resulting family of curves relating cost per acre and area of the spray irrigation field is shown on Plate TA-2-1. Thus, a cost figure may be added to the estimated cost of a proposed spray irrigation facility based on the land requirement and type of soil in a particular area.

Overland Runoff

Overland runoff is the controlled discharge by spraying or other means of liquid onto the land with the flow path being downslope sheet flow. This technique of land disposal is a potential consideration for sloping sites with impermeable subsoils. Some type of plant or tree cover is essential to control erosion and assist in renovation of the wastewater. All overland runoff sites in current operation are agricultural, supporting grass and hay culture. Superficial grading would be a general requirement at most potential overland runoff sites, since terraces or collection ditches are required for interception of the renovated water.

The degree and length of slope is dependent upon application rate, since the travel time across the ground must be long enough to allow renovation. The site must be steep enough to maintain desired flow without causing erosion and, at the same time, not allowing ponding and anaerobic conditions. Studies at the Campbell Soup Company cannery in Paris, Texas concluded that 175 feet can give effective renovation with slope criteria of 6% maximum and 2% minimum. It is suggested for planning purposes that a 300-foot slope distance and 2-6% slope range be adopted. In addition, the site should have 6 to 8 inches of good topsoil; also, for planning purposes, the application rate should be 2 inches per week.

Rapid Infiltration

Rapid infiltration is the controlled discharge of liquid onto land, at a rate measured in feet per week, with the flow path being high infiltration and percolation.

Most of the rapid infiltration sites described in the literature are in the Southwest and California. The basic purpose for most of the western sites is ground water recharge by applying disinfected secondary effluent.

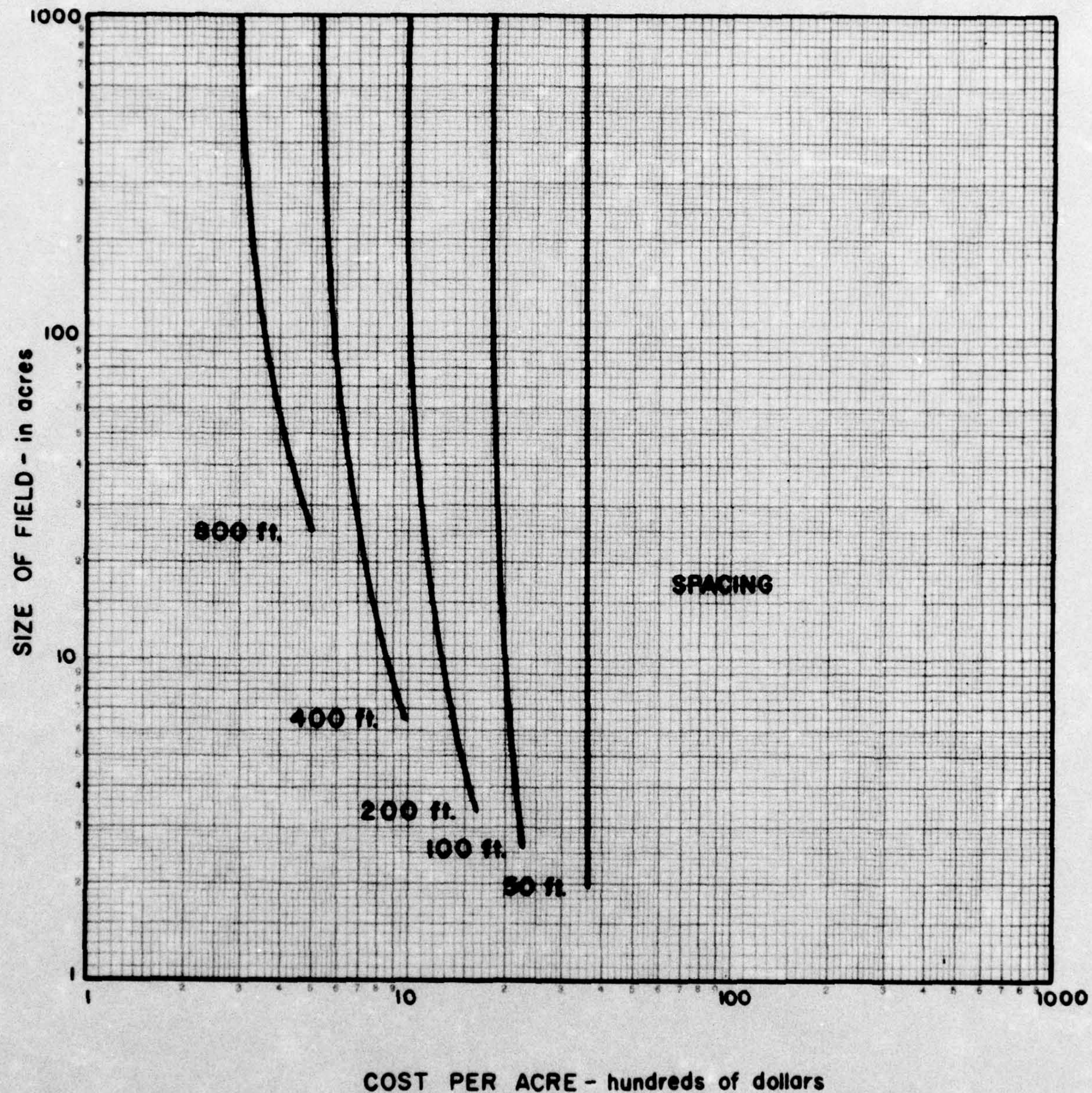
The great advantage of rapid infiltration sites is the ability to move large quantities of liquid in a relatively small land area, usually in a basin. Water depth is controlled by a weir at the end of the basin.

It is important to maintain aerobic conditions since long-term anaerobic conditions result in biochemical by-products which clog the soil pores and reduce infiltration and percolation. This controls the need for intermittent rest periods which dries the soil and restores aerobic conditions. The risk of anaerobic clogging is also the reason for maintaining a shallow depth of liquid in the basins. It is possible to maintain 6 inches to a foot in an aerobic state by surface reaeration.

Site investigations for rapid infiltration basins are especially critical. Data must be developed on subsurface soils to depths of 70 to 100 feet, and on ground water conditions including vertical and horizontal movements.

Assuming desirable conditions can be found, it should be possible to plan a rapid infiltration site for an average of one foot per day for 10 days followed by a 5-day rest period. A grass cover on the bottom is desirable to remove nutrients. The ground water table should be at least 15 feet from the bottom of the basin. Plate TA-2-2 shows the land requirement for this method of land disposal based on these criteria.

SUBSURFACE DRAINS



U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

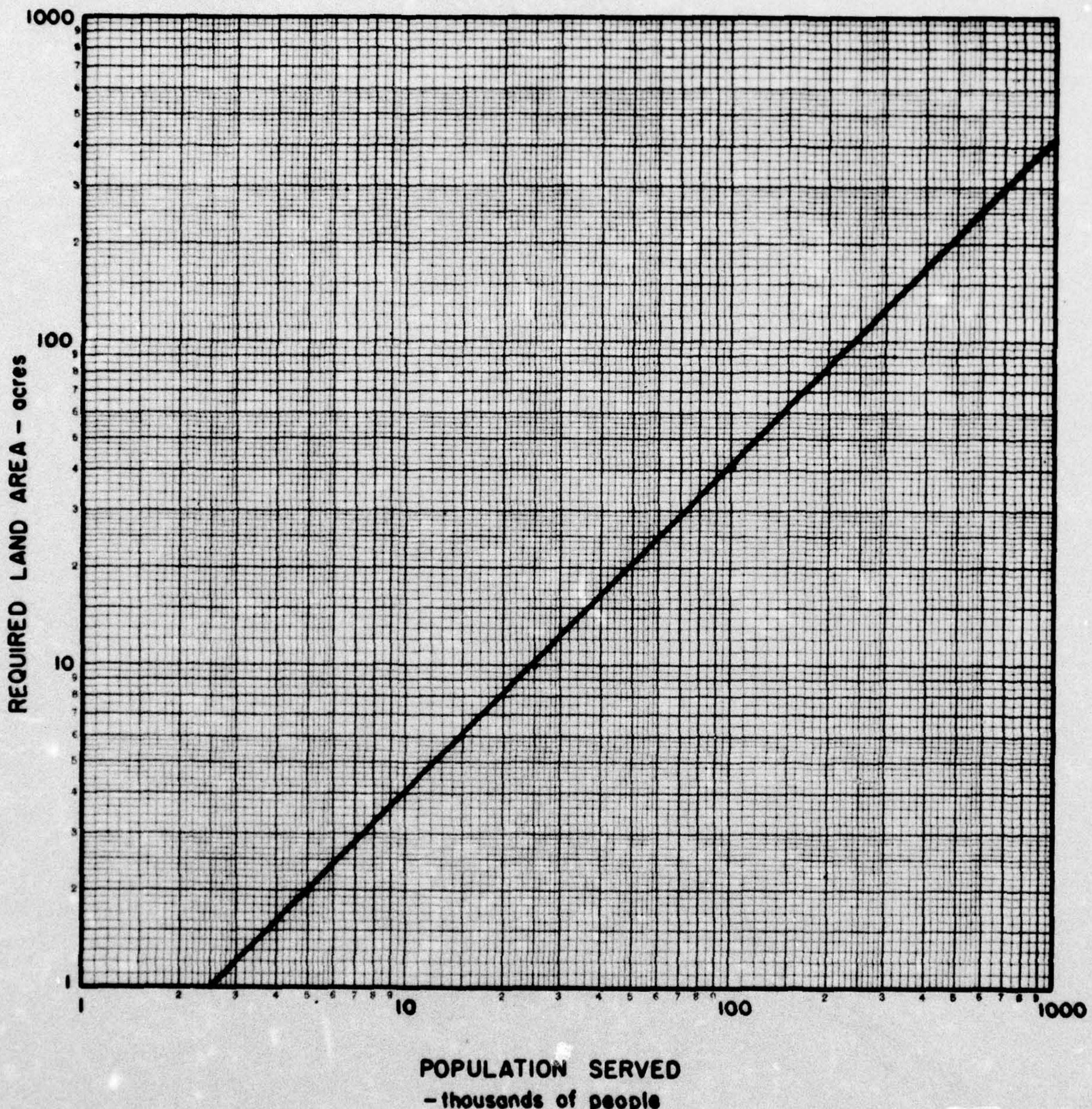
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

SUBSURFACE DRAINS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE TA-2-1

1.0 FT./DAY APPLICATION RATE
FOR 10 DAYS FOLLOWED BY
5 DAY DRY PERIOD
- USACE REPORT 72-1



U.S. ARMY ENGINEER DISTRICT, FORT WORTH CORPS OF ENGINEERS FORT WORTH, TEXAS
WASTEWATER MANAGEMENT STUDY COLORADO RIVER & TRIBUTARIES, TEXAS
LAND REQUIREMENT FOR INFILTRATION POND METHOD
TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR
PLATE TA-2-2

III. DESIGN TREATMENT LEVEL RATIONALE

A Rationale for Phased Implementation of Wastewater Treatment Processes

Technology and knowledge are presently available to design and construct wastewater treatment facilities capable of reclaiming an excellent quality water from wastewater. However, funding of such massive construction projects for the nation, state, or river basin cannot be accomplished in one sweeping construction program. Therefore, it becomes necessary to devise a schedule for implementation of advanced wastewater treatment facilities that allows for phasing of construction and funding. Phasing allows available funds and future planning for funding to move at a feasible and rational pace.

The following advanced wastewater treatment facility implementation schedule has been devised for the purpose of this study. The examples presented represent a biological treatment scheme since, at the present time, there are no other treatment methods utilized in the Basin. It should be recognized that these are presented only as examples, and a detail presentation of alternative treatment processes is presented elsewhere in the technical appendix.

In cognizance of the Federal Water Pollution Control Act Amendments of 1972, which state that publicly owned treatment works must provide "secondary" treatment of effluent by 1977 and the "best practicable waste treatment technology" by 1983 as a minimum of implementation, it was necessary to have a definition of these goals prior to preparation of all area-wide planning. To have awaited these definitions would have necessitated at least a six-month delay in the overall study effort. Therefore, the following rationale was utilized as a basis in establishing water quality goals in the Basin.

Secondary Treatment.

It was assumed for the purpose of this study that the effluent criteria desired for 1977 would be that expected from a properly operating "secondary" wastewater treatment plant receiving domestic wastewater. The effluent would contain a total BOD(5) level of 20 mg/l and a total suspended solids (TSS) level of 20 mg/l. This effluent would be disinfected and contain a minimum dissolved oxygen (DO) of 5.0 mg/l.

Best Practicable Treatment

It was further assumed that "best practicable" treatment by 1983 would be to reduce the BOD(5) and TSS to at least a level of 12 mg/l and 9 mg/l respectively. Inese levels can be achieved by several methods, but most practically by installation of filtration equipment. This equipment can be utilized to filter a portion of the total flow at a low filtration rate, and then the filtered portion and unfiltered portion could be blended at the proportions required to meet the BOD(5) and TSS level in the final effluent. Based on the literature and process review accomplished for this study and presented elsewhere in the technical Appendix, it was conservatively assumed that filtration would reduce BOD(5) and TSS constituent levels 60 and 80 percent respectively. Subsequent calculations indicated that the filtered portion would have to be two-thirds of the total flow to meet the 12/9 mg/l objective. Total filtration would be expected to reduce these constitutent levels to 8 mg/l and 4 mg/l respectively, and may be required in some sensitive receiving water quality areas. Another approach, utilizing the same capital outlay would be to operate the filtration units at high loadings (8 to 10 gpm/sq. ft.) and filter all effluent from the secondary process. The units would, however, require excessive operation and maintenance, and the method was not given further consideration. In addition to reducing the BOD(5) level, equipment should be installed to reduce the phosphorus concentration, as well as the ammonia-nitrogen and organic nitrogen levels. It is felt that the following processes may produce some associated further reduction of BOD(5) and TSS constituent levels; however, there are not sufficient data to make a justifiable prediction of what the BOD(5) and TSS levels would be.

Phosphorus is one of two principle nutrients that can attribute to excess algae and/or aquatic weed growth. Excess algae and/or aquatic weeds can create noxious tastes and odors in drinking water and are aesthetically unpleasing in surface water. Therefore, any first-stage advanced treatment should address itself to limiting the availability of this principal nutrient.

Phosphorus, measured as "P", can be reduced to 2 to 3 mg/l by two-stage addition of iron and/or aluminum salts. The first addition should be near the head of the treatment facility, with the second addition prior to filtration. This would generate approximately 80 percent reduction in the phosphorus discharged to receiving waters.

Reduction of the ammonia and organic nitrogen levels is desirable to eliminate the oxygen depletion downstream of the discharge point. The nitrogeneous oxygen requirement is significant and should be eliminated at the treatment facility.

Ninety to ninety-five percent of the ammonia and organic nitrogen can be converted to nitrite and nitrate nitrogen in a suspended biological floc system. This conversion is not, however, expected to effect any reduction in the total nitrogen level. It is possible for the bacteria responsible for the conversion, nitrosomonas and nitrobacters, to be cultivated in an activated sludge plant under optimum conditions. These conditions are: DO of the aeration basin equal to or greater than 2.0 mg/l, a sludge age of at least 4 days, pH range 7.8 to 8.0, and low heavy metals concentration. Many existing treatment facilities can be modified to produce these conditions; however, others will require the construction of additional aeration and clarification systems.

Summarizing the anticipated effluent characteristics assumed for the 1983 best practicable treatment level for domestic wastewater treatment facilities, it is expected that the effluent would have BOD(5) and TSS concentration of 12 mg/l and 9 mg/l respectively, phosphorus (as "P") of 2 to 3 mg/l, and an ammonia and organic nitrogen level of 1 to 2 mg/l, with adequate disinfection and DO of 5.0 mg/l.

Best Treatment Feasible

It was further assumed that "No Discharge of Pollutants" treatment by 1985 would be the best treatment feasible. The final phase of treatment processes to effect best treatment feasible to be implemented is expected to require denitrification and additional solids reduction. The increased solids removal can be accomplished by additional filtration capacity. Utilizing total filtration, the BOD(5) and TSS solids levels would be expected, for the purpose of this report, to be reduced to 8 mg/l and 4 mg/l, respectively.[1] This increased filtration will also decrease the colloidal phosphorus compounds generated by the metallic salts addition, although a coagulant aid will probably be required prior to filtration to decrease the phosphorus in the effluent to 0.2 mg/l.

---

(1) It should be noted that the literature indicates total filtration may attain a 5 mg/l BOD(5) level for some wastewaters.

Denitrification may be accomplished by an anaerobic biological process, preferably preceding the filtration units. The nitrification process previously implemented in the 1983 phase converted the ammonia and organic nitrogen to nitrite and nitrate nitrogen. The denitrification step breaks oxygen from the nitrite and nitrate nitrogen and nitrogen gas is released. This process, when coupled with nitrification, is expected to reduce the nitrogen level approximately 85 percent, and can reduce the total nitrogen level to 2 mg/l.

Summarizing the anticipated effluent quality for reasonable, most feasible treatment for domestic wastewater, it is expected that a BOD(5) of 8 mg/l, TSS of 4 mg/l, phosphorus measured as "P" of 0.2 mg/l, total nitrogen of 2.0 mg/l, fecal coliform equal to or less than MPN of 200 per 100 ml and a DO of 5 mg/l will be present. The remaining organic load could be reduced further by absorption on activated carbon if necessary; however, the process was not considered justifiable for a generalized treatment scheme at the present time, considering the associated costs and the capabilities of most municipalities.

A Rationale for Selection of Wastewater Treatment Processes to Meet A Highest Level of Treatment Objective.

The scope of this study includes the presentation of wastewater treatment alternatives capable of producing effluent constituent levels which represent the level anticipated for best treatment technically feasible with present-day technology. A review of the wastewater treatment literature was conducted to evaluate the reported effectiveness of the current treatment processes. Processes that were of particular interest were those demonstrated as capable of providing a wide flexibility for treating various substances associated with domestic sewage. The generalized treatment scheme diagrams presented herein are intended to be used as process flow diagrams rather than mechanical flow sheets or specific unit arrangements. Therefore, specific components such as clarifiers, sludge-handling facilities, recycling, or aeration units which are obviously an integral part of the general process, are not detailed on the diagram.

No generalized treatment processes were developed for industrial wastewaters which have such individualistic characterization that it was not practicable to select generalized treatment schemes to meet the constituent level requirements of the highest level of treatment objective. It was assumed, in accordance with new national legislation, that all industrial waste will receive adequate pretreatment prior to discharge to any municipal system.

The literature review produced a large variety of newly-developed treatment processes as well as variations in applications of basic processes. These units are attributed with various favorable treatment characteristics that are reported for pilot unit operations. Therefore, construction, operation, and maintenance costs are generated based upon scaled-up and anticipated cost values not attributed to actual construction and operating experience.

Another deficiency in evaluating treatment process efficiencies from a literature review is the specialized nature of most studies and efficiency evaluations. An industrial wastewater may have problem substances unique to the industry and requiring a treatment process that has favorable removal characteristics for the problem substance, but an overall lower efficiency for organic substances. An example of this type of specialized wastewater treatment would be the use of foam fractionation to accomplish separation of surface active agents in an industrial wastewater, with the result of only slightly reducing the COD. This type of specialized treatment process would not be justifiable for normal domestic wastewaters where the low concentration of surface active agents are normally destroyed in a biological reactor at the same time a higher degree of organics removal is effected.

The selection of complete wastewater treatment unit processes further requires a compatibility of individual processes and the proper sequence to maximize effective treatment and minimize cost. Due to the lack of specific wastewater characterization available for this River Basin study, it becomes increasingly important to select unit processes that have demonstrated flexibility of operation. This should not be interpreted as the only combination practicable or feasible for a specific wastewater. The engineer's preliminary wastewater survey for a specific community may reveal a wastewater characterization that is unique and may be more effectively treated by a different combination of processes.

The various unit processes are presented as schematic diagrams. It is not within the scope of this study to dictate or defend geometric configurations of individual units. The scope of a river basin plan should present direction and alternatives, not construction materials or geometric configuration of designs.

Biological Treatment Process

Biological treatment of domestic wastewater is the most popular mode of treatment utilized today and for the forseeable future. Presently, the activated sludge process, with numerous modifications, is the most popular biological treatment scheme. These modified activated sludge processes include conventional activated sludge, step aeration, contact stabilization and extended aeration. The last two schemes are the most popular for small communities due to the simplicity of construction.

Contact stabilization plants are often considered as "Package Plants" due to the popularity of constructing concrete or metal tanks on the ground for serving small communities. However, the contact stabilization mode of operation is not limited to package plant design.

The extended aeration mode of treatment is particularly applicable to small rural communities, due to the minimal operations associated with the plant. This mode of wastewater treatment has been constructed as metal "Package Plants" and in the form of oxidation ditches, as well as concrete tanks placed on or in the ground.

The activated-sludge biological treatment process will produce a good quality secondary effluent. This effluent is compatible to further treatment by numerous tertiary treatment processes.

Tertiary treatment can be accomplished by chemical, physical, and biological schemes. Carbonaceous and nitrogenous oxygen-demanding substances are generally removed or reduced together with nutritional compounds of phosphorus and nitrogen. Also, any color associated with wastewater would be removed and the effluent disinfected.

Numerous tertiary treatment processes are available to accomplish the high level of treatment required to meet the objective. The following system, presented schematically on Plate TA-3-1, was selected due to the flexibility of the individual processes, their ability to treat various substances that may be encountered in domestic wastewaters, and their compatibility with biological secondary treatment.

Phosphorus removal can be accomplished by chemical precipitation with aluminum salts. It should be recognized that an iron salt could be substituted for alum if a source of iron salts is more readily available.

In this process, the addition of a polymer to improve the removal of the precipitate may also be required. To effect best treatment practicable, the aluminum salt should be added at the two points illustrated on Plate TA-3-1.

Phosphorus removal may also be accomplished by a high lime dosage, clarification, and neutralization of a wastewater. This method of phosphorus removal is also highly effective in reduction of BOD and suspended solids. However, the BOD and suspended solids reduction is not required prior to biological treatment, and high lime treatment becomes an expensive method of phosphorus removal in the biological treatment scheme. Therefore, the addition of aluminum or iron salts is recommended for phosphorus removal in the biological treatment scheme.

Ammonia-Nitrogen may be removed by stripping at a pH of 11.0 by flow through an ion exchanger containing clinoptilolite resin, or by biological nitrification. The biological nitrification step illustrated on Plate TA-3-1 was selected because it will also hydrolyze the organic nitrogen compounds present to ammonia. The activated-sludge process is suitable for biological nitrification by converting ammonia and organic nitrogen to nitrite and nitrate nitrogen.

Denitrification can be accomplished by an anaerobic biological process where nitrogen gas is released to the atmosphere. This process, as presented on Plate TA-3-1, is commonly conducted in a closed vessel containing a media for the bacterial growth with a carbon source supplied by methanol. It is anticipated that this process will have improved operational characteristics as more are placed in service and experience is gained.

Filtration may be affected by gravity or pressure, utilizing sand or mixed media or by microscreening to produce an acceptable effluent. There are numerous systems available to satisfy this process requirement and selection would be on a cost analysis for the specific wastewater treatment plant location.

Activated Carbon columns are proposed to polish the effluent to the desired quality. The process has many flow variations available from several different suppliers. The polishing step may utilize ozonation; however, ozone is an extremely poisonous gas and its use must be carefully considered.

Disinfection, as practiced today in the United States, is generally by the application of chlorine. Generally, chlorine gas is dissolved in the wastewater which is retained in a basin for a contact period prior to discharge. Effluent may also be disinfected by ozonation, a common practice in Europe, but again, the safety and cost aspects must be carefully weighed.

The effluent from the denitrification step will have a low dissolved oxygen concentration and should be aerated prior to discharge. Since aeration after chlorination will strip the free chlorine from the effluent, it is advisable to aerate the effluent prior to the introduction of chlorine.

Physical-Chemical Treatment Process

Treatment of domestic wastewater by physical and chemical processes alone has gained increasing popularity in the United States in recent years. A basic schematic of two-flow and process routes is presented on Plate TA-3-2.

The first step in this treatment scheme is primary clarification with the addition of lime in sufficient quantity to raise the pH of the wastewater to 11.0. The system utilizes lime sludge recycle and provides significant solids and phosphorus reduction.

At pH of 11.0, the wastewater can be passed through a stripping tower which will remove significant amounts of ammonia-nitrogen. This has been presented as Alternative I on Plate TA-3-2.

Alternative II presents the option of using the ion exchanger with clinoptilolite resin. The selection of this process would be based upon the availability of the resin and the operational characteristics desired by the owner. After the high-lime treatment process, the wastewater requires neutralization. Neutralization is normally accomplished by the addition of carbon dioxide.

Filtration and activated carbon treatment for physical-chemical treatment are the same processes previously described for the biological mode of treatment; however, the activated carbon process is considerably more extensive due to the higher soluable organic load delivered to the process.

Aeration and disinfection by the previously discussed techniques are applicable to physical-chemical treatment processes as presented on Plate TA-3-2.

Land Disposal Treatment Process

Land disposal of effluent from a secondary wastewater treatment facility has numerous advantages. The effluent serves as a source of water, phosphorus, nitrogen, and other essential elements required for growth of vegetation, and the resulting removal of these nutrients by vegetation uptake affects tertiary treatment to the applied wastewater.

Plate TA-3-3 illustrates three land-disposal techniques whose applicability are determined by climatic, topographic, and soil characteristics. Land disposal techniques may collect the treated wastewater for ultimate discharge to a receiving stream or allow evapotranspiration and seepage to ground water to consume the total flow. A detailed technical discussion of land disposal criteria is presented elsewhere in the technical appendix.

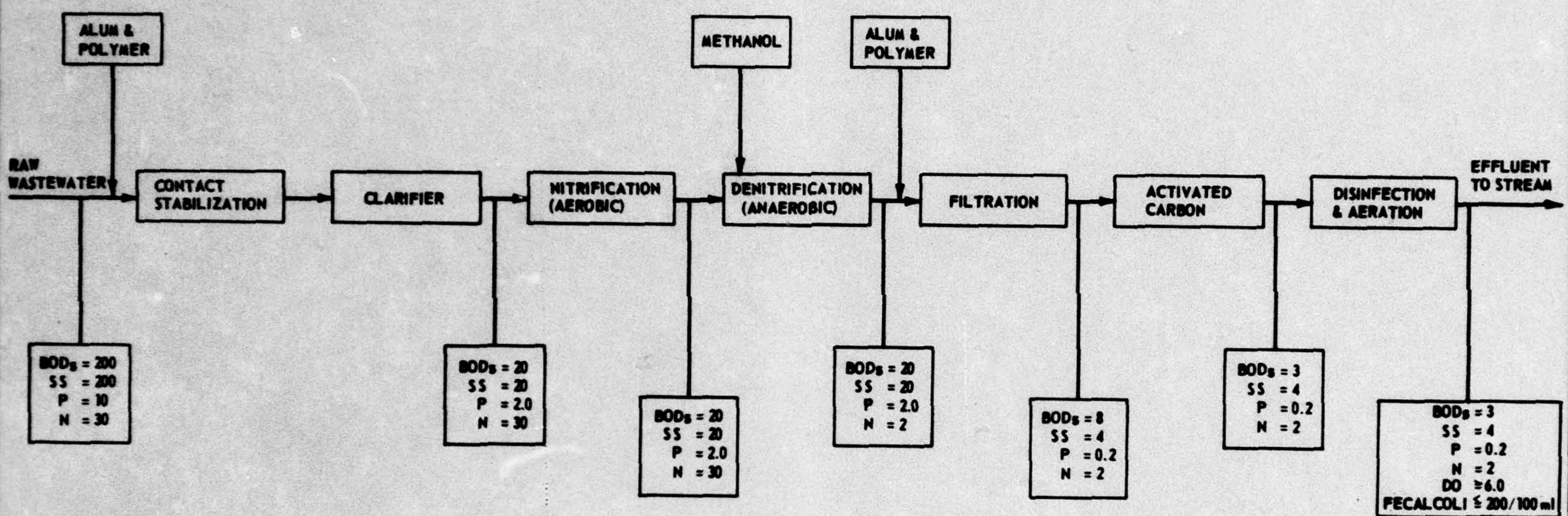
The Overland Runoff land disposal technique allows the applied wastewater to flow in a thin sheet over the land supporting vegetation. The effluent is then normally collected for discharge.

Rapid Infiltration is an acceptable treatment technique for treating wastewater in an area of high soil permeability and depth. The wastewater is placed in shallow ponds for infiltration into the soil. Wastewater application to the ponds is intermittent, thereby maintaining an aerobic soil surface condition.

Spray Irrigation is the most commonly practiced method of land disposal. The wastewater is applied by sprayers to land containing vegetation. The effluent may be collected by an underdrain system, a well system, or allowed to form a ground water mound. The wastewater application is shifted periodically to various areas to eliminate ponding of the applied wastewater. The vegetation is harvestable, with the applied nutrients being removed in the harvest. Plants utilizing large amounts of water and nutrients are more suited for this type of land-disposal system.

All of the various treatment schemes represent present-day technology for treating wastewaters to a high degree. The field of wastewater treatment process development and refinement is continously undergoing change. New advances in wastewater treatment equipment are constantly being brought forth, making present-day experimental techniques practical and feasible for large-scale operations.

PROPOSED NEW TREATMENT FACILITIES



LEGEND

BOD_5 = FIVE DAY BIOCHEMICAL OXYGEN DEMAND
SS = TOTAL SUSPENDED SOLIDS
P = TOTAL PHOSPHORUS
N = TOTAL NITROGEN

NOTE: ALL PARAMETERS IN MG/L

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

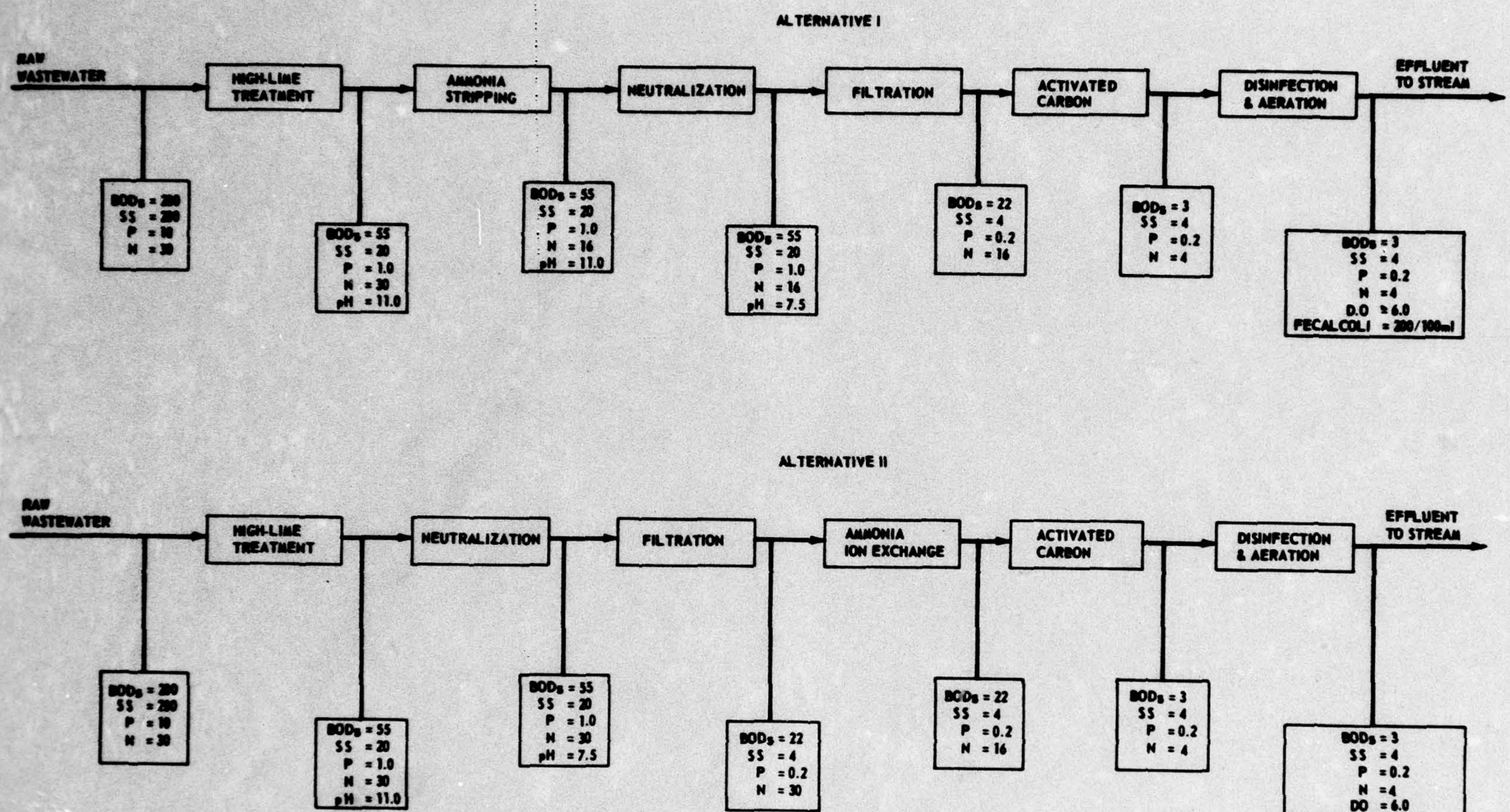
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

EXPECTED WASTEWATER CHARACTERISTICS BIOLOGICAL PROCESS

TURNER, COLLIE & BRADEN, INC. - HOUSTON/PORT ARTHUR

PLATE: TA-3-1

PROPOSED NEW TREATMENT FACILITIES



LEGEND

BOD_5 = FIVE DAY BIOCHEMICAL OXYGEN DEMAND
SS = TOTAL SUSPENDED SOLIDS
P = TOTAL PHOSPHORUS
N = TOTAL NITROGEN

NOTE: ALL PARAMETERS IN MG/L

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

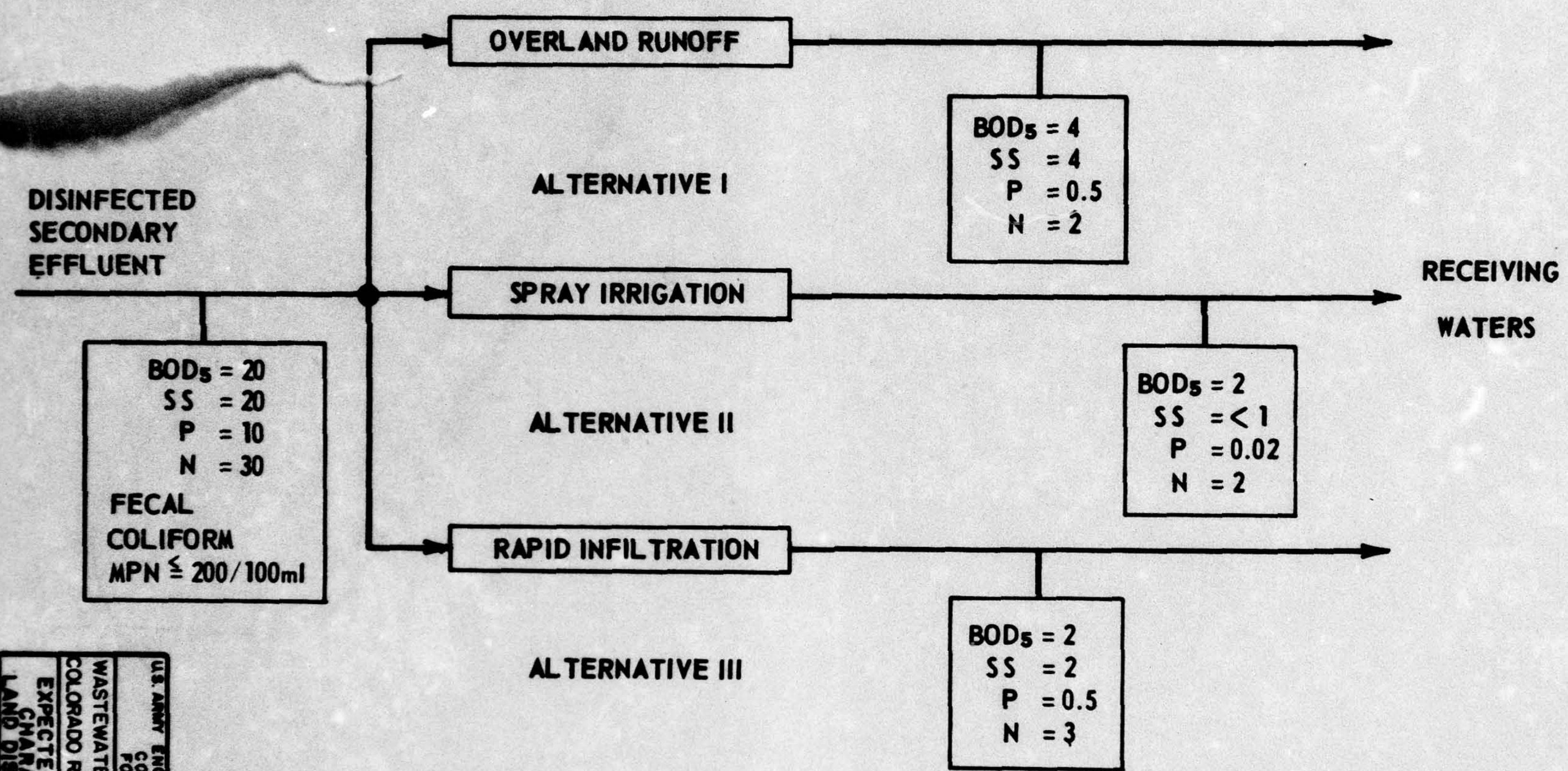
WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

EXPECTED WASTEWATER CHARACTERISTICS PHYSICAL-CHEMICAL PROCESS

TURNER, COLLIE & BRADEN, INC. - HOUSTON/PORT ARTHUR

PLATE: TA-3-2

TERTIARY TREATMENT BY LAND DISPOSAL



LEGEND

BOD_5 = FIVE DAY BIOCHEMICAL OXYGEN DEMAND
SS = TOTAL SUSPENDED SOLIDS
P = TOTAL PHOSPHORUS
N = TOTAL NITROGEN

NOTE: ALL PARAMETERS IN MG/L

U.S. ARMY ENGINEER DISTRICT, FORT WORTH
CORPS OF ENGINEERS
FORT WORTH, TEXAS

WASTEWATER MANAGEMENT STUDY
COLORADO RIVER & TRIBUTARIES, TEXAS

EXPECTED WASTEWATER CHARACTERISTICS LAND DISPOSAL PROCESS

TURNER, COLLIE & BRADEN, INC. HOUSTON/PORT ARTHUR

PLATE: TA-3-3

IV. EVALUATION OF WASTEWATER TREATMENT PROCESS EFFICIENCIES

Introduction

Prior to developing wastewater treatment schemes, a review of the current technology was necessary. This section presents a breakout of various unit processes and their reported removal efficiencies for wastewater constituents. This review of process efficiencies establishes a basis for developing complete wastewater treatment plant treatment schemes. The individual process efficiencies allow for evaluating various combinations of processes to produce the desired level of treatment. The section of unit process combinations is presented elsewhere in the technical appendix.

The evaluation of removal efficiencies of wastewater treatment processes was accomplished by reviewing published data on existing plant operations. Data on pilot plants were also reviewed and utilized where applicable. The primary source of this data was Environmental Protection Agency publications describing existing wastewater treatment plants operations and efficiencies. Data on land disposal techniques and efficiencies were available in various reports published by the Corps of Engineers, in technical literature, and in numerous special reports. The efficiency ranges for the various processes do not necessarily reflect the highest value reported. Pilot plant operations in many situations, as would be expected, report higher removal efficiencies than full-scale treatment facilities. Where possible, the majority of reported unit process efficiencies were used to present realistic and attainable removal values, not necessarily the highest efficiency reported.

Presentation of Data

The data is presented in tables divided into primary, secondary, and tertiary treatment processes. It should be recognized that there may be some overlap of these treatment processes. The unit processes listed in the tables do not represent all of the processes now under development. The area of research and development of wastewater treatment processes is in constant flux. The processes presented represent developed and available units, most of which are in operation at various installations throughout the country.

TABLE IV-1

PRIMARY TREATMENT PROCESS EFFICIENCIES

Treatment Process	Parameter*	% Removed
Gravity Settling		
Raw Wastewater	BOD	25 to 40
	SS	40 to 70
		-
Iron and Polymer Addition Prior to Settling	BOD	55 to 60
	SS	75 to 78
	P	60 to 90
Alum Addition Prior to Settling	BOD	55 to 60
	SS	75 to 78
	P	80 to 85
Lime Addition Prior to Settling	BOD	70 to 72
	SS	78 to 88
	P	77 to 90
Flotation		
Raw Wastewater	BOD	25 to 35
	SS	40 to 65
	P	-

TABLE IV-2

SECONDARY TREATMENT PROCESS EFFICIENCIES

Treatment Process	Parameter*	% Removed
Biological		
Trickling Filter	BOD	75 to 85
	P	5 to 10
Activated Sludge	BOD	80 to 95
	P	5 to 10
Chemical-Physical		
Carbon Adsorption	COD (Industrial)	60 to 75
	BOD (Domestic)	90

TABLE IV-3

TERTIARY TREATMENT PROCESS EFFICIENCIES

Treatment Process	Parameter*	% Removed
Filtration		
Down Flow	BOD	50 to 70
	SS	75 to 90
Up Flow	SS	85
Micro Screeners	BOD	30 to 80
	SS	55 to 90
Chemical-Physical		
Carbon Adsorption (effluent from filter)	BOD	60 to 75
Chemical Addition:		
(1) To trickling filter		
(a) alum	P	96
(b) iron	P	85
(2) To activated sludge		
(a) alum	P	88
(b) sodium aluminate	P	83
(3) After biological treatment		
Lime - 2 stage addition		
(a) unfiltered	P	95 to 96
(b) filtered	BOD	77
	P	98 to 99

TABLE IV-3 (Cont'd)

Treatment Process	Parameter*	% Removed
Nitrogen Removal		
Biological nitrification and Denitrification	NH_3 - N	80 to 90
Ammonia-nitrogen Stripping (pH=11.0)	NH_3 - N	50 to 95
Land Disposal		
Spray Irrigation	BOD	99
	SS	99
	N	80 to 90
	P	99
Overland Runoff	BOD	80
	SS	80
	N	80
	P	80
Rapid Infiltration	BOD	99
	SS	99
	N	80
	P	90

* BOD = biochemical oxygen demand; SS = suspended solids; P = Phosphorus reported as P; COD = Chemical oxygen demand NH_3-N = ammonia nitrogen; N = total nitrogen

V. BASE DATA AND BIBLIOGRAPHY

It is the purpose of this section of the Appendix to present a listing of all reports, publications, papers, or guidance collected and utilized during the Wastewater Management Study. For retrieval purposes, a filing system was initiated utilizing computer cards that would allow insertions or alterations without a major typing revision. The following summary, therefore, has been reproduced directly from the computer listing to eliminate a significant typing effort.

As publications were received or gathered throughout the course of the study, new categories were either added to the end of the list or the publications were inserted under existing topics. The resultant listing, therefore, is not optimal; however, since almost all of the publications must be returned to the original donor, the level of effort required to refine the listing is not justified.

Sincere appreciation is expressed to the Governor's Office of Planning Coordination, the Texas Water Quality Board, all Regional Planning Councils, many municipalities, numerous consulting engineering firms, and many others who contributed data and reports toward this study effort.

AD-A036 846 ARMY ENGINEER DISTRICT FORT WORTH TEX F/G 13/2
WASTEWATER MANAGEMENT PLAN. COLORADO RIVER AND TRIBUTARIES, TEX--ETC(U)
SEP 73

UNCLASSIFIED NL

2 OF 2
AD
A036846

END
DATE
FILMED
4-77

TABLE IV-3 (Cont'd)

Treatment Process	Parameter*
Nitrogen Removal	
Biological nitrification and Denitrification	NH_3 - N
Ammonia-nitrogen Stripping (pH=11.0)	NH_3 - N
Land Disposal	
Spray Irrigation	BOD
	SS
	N
	P
Overland Runoff	BOD
	SS
	N
	P
Rapid Infiltration	BOD
	SS
	N
	P

* BOD = biochemical oxygen demand; SS = suspe
P = Phosphorus reported as P; COD = Che
NH_3-N = ammonia nitrogen; N = total nitrogen

D. INTERIM TECHNICAL REVIEW OF BIOLOGICAL NITROGEN REMOVAL COSTS AND EFFECTIVENESS (MARCH 31, 1972)
E. INTERIM TECHNICAL REVIEW OF CHEMICAL PHOSPHOROUS REMOVAL COSTS AND EFFECTIVENESS (MARCH 1, 1972)
F. PRELIMINARY TECHNICAL REVIEW OF ACTIVATED CARBON TREATMENT COSTS AND EFFECTIVENESS (MARCH 1, 1972)
G. TECHNICAL NOTE ON ESTABLISHMENT OF WATER QUALITY LEVELS FOR CRITICAL POLLUTANTS IN EFFLUENTS FROM WASTEWATER TREATMENT PROCESSES (JUNE 7, 1972)
H. TECHNICAL NOTE ON THE OCCURENCE OF VIRUSES IN WASTEWATER AND DISINFECTION PROCEDURES (JUNE 1, 1972)
I. TECHNICAL NOTE ON ESTABLISHMENT OF WATER QUALITY LEVELS FOR CRITICAL CONSTITUENTS IN EFFLUENTS FROM WASTEWATER TREATMENT PROCESSES (JUNE 30,1972) NOTE SEE CE-X-G
J. DA,OCE, WASTEWATER MANAGEMENT PROGRAM STUDY PROCEDURE, MAY 72
K. PRELIMINARY GUIDELINES FOR ASSESSMENT OF SOCIAL, ECONOMIC, AND ENVIRONMENTAL EFFECTS OF CIVIL WORKS PROJECTS
L. NOTES ON STORMWATER RUNOFF
M. COMPUTER APPLICATION TO STREAMFLOW SYNTHESIS AND RESERVOIR REGULATION
N. TECHNICAL NOTE ON THE DISPOSAL OF RESIDUES FROM SELECTED WASTEWATER TREATMENT PROCESSES, JULY 1972
O. URBAN STUDIES PROGRAM - SELECTED BACKGROUND INFORMATION
P. WASTEWATER MANAGEMENT PROGRAM - PROCEDURE - ADVANCE COPY
Q. FOUR LAND TREATMENT SITES CURRENTLY IN OPERATION IN THE U. S. (SEPTEMBER 72)
R. THE EFFECTS OF STRIP MINING UPON NAVIGABLE WATERS AND THEIR TRIBUTARIES, JULY 1972
S. THE USE OF LAND AS A METHOD OF TREATING WASTEWATER (DEC.72)
T. REACTIONS OF HEAVY METALS WITH SOILS, NOV 72
U. WASTE INTO WEALTH, FALL 72

FHA COMPREHENSIVE WATER SEWER PLAN

A. LAMPASAS COUNTY - JULY 70
B. MILLS COUNTY - JUNE 71
C. SAN SABA COUNTY - JULY 71
D. BASIN COVERAGE
E. COCHRAN COUNTY - MAY 1968
F. LYNN COUNTY - 1969
G. LLANO COUNTY - JANUARY 1972
H. MATAGORDA COUNTY - 1970
I. FAYETTE COUNTY - SEPTEMBER 1968
J. HAYS COUNTY - MAY 1969
K. GILLESPIE COUNTY - SEPT 1971
L. COKE COUNTY - APRIL 1968
M. GAINES COUNTY - MAY 1969
N. BASTROP COUNTY - 1970
O. BORDEN AND DAWSON COUNTIES - 1972
   1. RURAL ENVIRONMENTAL ASSISTANCE PROGRAMS
P. COLORADO AND WHARTON COUNTIES - 1972

F. PUBLIC FACILITIES (NOV 70)
G. PUBLIC FACILITIES (UTILITIES AND DRAINAGE) (OCT 70)
H. SANITARY LAYOUT

CITIES OF MIDLAND AND ODESSA
A. MIDLAND PLAN - NOV 70
B. MIDLAND - REPORT ON WATER SUPPLY AND TREATMENT, 1968
C. MIDLAND-ODESSA--AN ANALYSIS OF THE ECONOMIC BASE FOR URBAN
D. MIDLAND-ODESSA REGIONAL TRANSPORTATION STUDY
1. VOL. 1 - ORIGIN-DESTINATION SURVEY, 1965
2. VOL. 2 - BASIC ELEMENTS AND PLAN, 1965
3. VOL. 3 - INTERIM REPORT, 1965-1969
E. ODESSA - ECONOMIC BASE POPULATION AND LAND USE, JUN 1972
F. ODESSA - SUMMARY REPORT - POPULATION AND LAND USE, MAY 1972
DEVELOPMENT AUG 65

WEST CENTRAL TEXAS COUNCIL OF GOV'TS.
A. COMPREHENSIVE PLANNING STAGE II 1970-1990
B. SUMMARY REPORT (FEB 70)
C. SUPPLEMENT REPORT (FEB 70)
D. TECHNICAL APPENDIX (FEB 70)
E. REGIONAL DATA BOOK 1971
F. REGIONAL ECONOMIC BASE AND INDUSTRIALIZATION STUDY
G. REGIONAL RECREATIONAL DEVELOPMENT APPRAISAL
H. RURAL COMPREHENSIVE WATER AND SEWER PLAN 1970-1990
1. VOL. 1
2. VOL. 2

DATA PREPARED FOR THE DEPT. OF THE ARMY CORPS. OF ENGINEERS
A. DEPT. OF THE ARMY, OCE, ENGINEERING AND DESIGN
WASTEWATER MANAGEMENT SERIES
1. ETL 1110-2-500 GENERAL GUIDANCE
2. ETL 1110-2-501 LAND DISPOSAL
3. ETL 1110-2-502 SLUDGE HANDLING AND DISPOSAL
4. ETL 1110-2-503 LAND DISPOSAL METHOD - DESIGN CRITERIA
5. ETL 1110-2-504 SLUDGE DISPOSAL
6. ETL 1110-2-505 REAL ESTATE GUIDANCE
7. ETL 1110-2-506 ON-LAND TREATMENT EXPERIENCE
8. ETL 1110-2-507 TREATMENT OF URBAN STORMWATER RUNOFF
9. ETL 1110-2-508 PILOT PLANT DATA FOR PLANT TREATMENT SYSTEMS
10. ETL 1110-2-509 GROUNDWATER CONSIDERATIONS IN DISPOSAL OF WASTEWATER ON THE LAND
11. ETL 1110-2-310 EFFECTS OF CROP PRODUCTION TECHNOLOGY ON THE ENVIRONMENT
12. ETL 1110-2-511 ON LAND APPLICATION OF WASTEWATERS AND SLUDGES
13. ETL 1110-2-513 ON LAND DRAINAGE TECHNIQUES
B. INTERIM TECHNICAL REVIEW OF ELECTRODIALYSIS AND REVERSE OSMOSIS COSTS AND EFFECTIVENESS (MAY 1, 1972)
C. INTERIM TECHNICAL REVIEW OF SELECTED FILTRATION PROCESSES COSTS AND EFFECTIVENESS (MARCH 10, 1972)

PUBLICATIONS GATHERED BY THE U.S. ARMY CORPS OF ENGINEERS AND THE A/E TO SERVE AS BASE DATA FOR THE EXECUTION OF THE COLORADO RIVER WASTEWATER MANAGEMENT STUDY

ALAMO AREA COUNCIL OF GOVERNMENTS WATER RESOURCE MANAGEMENT PLAN
- A. VOL 1-METHODOLOGY ANALYSIS OF WATER RESOURCE AREAS (DEC 71)
- B. VOL 2-URBAN WATER RELATED SERVICES (DEC 71)
- C. VOL 3-SHORT RANGE PROGRAM 1970-1975 (DEC 71)

ANDREWS, TEXAS-REPORT ON WATER SYSTEMS ANALYSIS (APR 70)

BALLINGER, TEXAS-COMPREHENSIVE CITY PLAN 1970-1995
- A. BASE STUDIES POPULATION AND GOALS
- B. CAPITAL IMPROVEMENTS
- C. COMMUNITY FACILITIES AND HOUSING
- D. LAND USE AND NEIGHBORHOOD ANALYSIS
- E. THOROUGHFARES, TRANSPORTATION AND CENTRAL BUSINESS DISTRICT

COLEMAN, TEXAS-COMPREHENSIVE DEVELOPMENT PLAN (OCT 70)

CONCHO VALLEY COUNCIL OF GOVT'S
- A. CONCHO VALLEY SOIL AND WATER CONSERVATION NEEDS INVENTORY (JAN 72)
- B. OPEN SPACE PLANNING (APR 72)
- C. CONCHO VALLEY ANNUAL REPORT (1969-70)
- D. LAND RESOURCE STUDY
  - 1. VOL 1-REGIONAL OVERVIEW AND ALTERNATIVE PLANNING POLICIES
  - 2. VOL 2-PHYSICAL RESOURCE INVENTORY
  - 3. VOL 3-OPEN SPACE RECREATION AND TOURISM
  - 4. VOL 4-DEMOGRAPHIC AND ECONOMIC PROFILE
- E. REPORT ON SEWAGE AND WASTE COLLECTION, SEWAGE TREATMENT, AND RELATED WATER QUALITY FOR TOM GREEN COUNTY
- F. COMPREHENSIVE WATER AND SEWER PLAN FOR TOM GREEN, CONCHO, MENARD COUNTIES (1970-1990)
- G. FIVE COUNTY COMPREHENSIVE WATER & SEWER PLAN

THE HIGHLAND LAKES SYSTEM COMPREHENSIVE WASTEWATER STUDY 1970-1990
- A. PHASE 1-POPULATION AND GROWTH
- B. PHASE 2-EXISTING FACILITIES AND CONDITIONS
- C. PHASE 3-CONCEPTUAL DESIGN FOR AREAWIDE FACILITIES
- D. PHASE 4-IMPLEMENTATION OF THE RECOMMENDED PLANS

LAMESA-DAWSON COUNTY, TEXAS
- A. THE COMPREHENSIVE PLAN - APR 71
- B. BASE STUDIES (NOV 69)
- C. CAPITAL IMPROVEMENTS (MAR 71)
- D. CIRCULATION (AUG 70)
- E. LAND USE (MAY 70)

UPTON COUNTY-COMPREHENSIVE PLAN (WATER AND SEWER) OCT 69

U.S. DEPT. OF THE INTERIOR REPORTS

A. ANNUAL COMPILATION AND ANALYSIS OF HYDROLOGIC DATA FOR URBAN STUDIES IN THE AUSTIN METROPOLITAN AREA
   1. 1967
   2. 1968
   3. 1969 (2 COPIES)
   4. 1970
B. COST AND PERFORMANCE ESTIMATES FOR TERTIARY WASTEWATER TREATING PROCESSES, REPT. TWRC-9, JUNE 1969
C. FACTORS CONTRIBUTING TO UNUSUALLY LOW RUNOFF DURING THE PERIOD 1962-68 IN THE CONCHO RIVER BASIN
D. HYDROLOGY FOR URBAN LAND PLANNING - A GUIDEBOOK ON THE EFFECTS OF URBAN LAND USE
E. EVALUATION PROCESSES IN WATER RESOURCES MANAGEMENT AND DEVELOPMENT, 1971
F. TEXAS BASINS PROJECT, FEB 1965
G. COST OF WASTEWATER TREATMENT PROCESSES
H. INDEX OF SURFACE WATER STATIONS IN TEXAS, 1971
I. LIMNOLOGICAL INVESTIGATIONS OF TEXAS IMPOUNDMENTS FOR WATER QUALITY MANAGEMENT PURPOSES

WATER QUALITY DATA - USGS UNPUBLISHED RECORDS SUBJECT TO REVISION

A. COPY 1
B. COPY 2

GALVESTON BAY PROJECT-REGIONAL SYSTEMS TASK PHASE 1 (DEC 71)

SMALL REPORTS

A. COSTS AND MANPOWER FOR MUNICIPAL WASTEWATER TREATMENT PLANTS OPERATION AND MAINTENANCE 1965-1968
B. PROPOSED PROGRAM OF SEPTIC TANK INVESTIGATION AND LICENSING FOR LCRA
C. SCS.-.TEXAS TECH UNIV. WORKSHOP - COMMITTEE ON FEEDLOT WASTE JULY 29, 1971
D. PLANNING AND DEVELOPING COMMUNITY WATER AND WASTE DISPOSAL FACILITIES, USDA
E. THE PILOT WASTEWATER MANAGEMENT PROGRAM, INTERIM REPT., SECTY OF THE ARMY
F. DEVELOPMENT OF A MATH MODEL FOR THE SIMULATION OF FLAT-LAND WATERSHED HYDRAULICS
G. ENVIRONMENTAL EVALUATION, POHICK CREEK WATERSHED PROJECT MARCH 1972
H. PRELIM. DESIGN REPORT, TERTIARY WASTE TREATMENT PLANT SOUTH LAKE TAHOE PUD
I. WATER POLLUTION, DOMESTIC WASTES, JUNE 1971
J. IS WATER QUALITY ENHANCEMENT FEASIBLE, ASCE, MAR 1970
K. MISCELLANEOUS PAPERS AND REPORTS
   1. A PRACTICAL GUIDE TO WATER QUALITY STUDIES OF STREAMS
   2. WATER QUALITY SIMULATION MODEL, ASCE, OCT 1971

3. GENERAL HYDROLOGIC SYST. MODEL, ASCE, JUN 1971
4. ECONOMICS OF WATER QUALITY AND WASTEWATER CONTROL, ASCE, APR 1972
5. BASIN MANAGEMENT TECHNIQUES FOR SEWERAGE AGENCIES ASCE, JUNE,1972
6. CONCEPTUAL HYDROLOGIC MODELS FOR URBANIZING BASINS ASCE, JULY, 1972
7. QUALITY OF SURFACE IRRIGATION RUNOFF WATER, ASAE 71
8. MOVEMENT OF NITRATES UNDER IRRIGATED AGRICULTURE, ASAE 72
9. PREDICTING SURFACE RUNOFF FROM AGRICULTURAL WATERSHEDS, ASAE 71
10. MOVEMENT OF PESTICIDES BY RUNOFF AND EROSION, ASAE 71
11. EVALUATING THE RISK OF INVESTMENT IN ENVIRONMENTAL CONTROL PRACTICES, ASAE 71
12. SURFACE WATER QUALITY IS INFLUENCED BY AGRICULTURAL PRACTICES, ASAE 71
13. CHANGES IN WATER YIELD BY AGRICULTURAL PRACTICES, ASAE 71
14. ADSORPTION AND TRANSPORT OF AGRICULTURAL CHEMICALS IN WATERSHEDS, ASAE 71
15. NITRATE CONCENTRATIONS IN GROUND-WATER BENEATH A BEEF CATTLE FEEDLOT, ASAE 71

L. FEDERAL LAND IN COLORADO BASIN
M. BRAZOS SALT POLLUTION SURVEY REPORT
N. A GUIDE TO THE DISPOSAL OF HOUSEHOLD SEWAGE
O. GUIDELINES FOR DESIGN OF EVAPORATIVE BED SEPTIC SYSTEMS
P. UPPER TRA COMP. SEWERAGE PLAN - ENVIRONMENTAL ASSESSMENT
Q. BALLINGER, ENGR. STUDY OF SEWAGE TREATMENT FACILITIES
R. CHARACTERISTICS AND EFFECTS OF CATTLE FEEDLOT RUNOFF, MAY 70
S. USE OF SEWAGE EFFLUENT AS COOLING WATER FOR STEAM-ELECTRIC GENERATION, MARCH 69

THE COASTAL RESOURCES MANAGEMENT PROGRAM OF TEXAS

A. APPENDICES TO INTERIM REPORT-VOL. 1
B. APPENDICES TO INTERIM REPORT-VOL. 2

COLORADO RIVER BASIN

A. COLORADO RIVER BASIN TABULATION PRINT-OUT
   1. STREAM MONITORING
   2. WASTE CONTROL ORDERS
   3. SELF REPORTING DATA
B. HISTORICAL DATA FOR DRYLAND AND IRRIGATED CROPS BY COUNTIES FOR THE YEARS 1960 & 1970
   HISTORICAL WATER INTAKE (ACRE-FEET) DATA FOR IRRIGATED AGRICULTURE FOR THE YEARS 1960 & 1970
C. 1960 & 1970 URBAN AND RURAL POPULATION
   1960 INDUSTRIAL EMPLOYMENT BY STANDARD INDUSTRIAL CLASSIFICATION
   URBAN AND RURAL POPULATION PROJECTIONS FOR YEARS 1975, 1990, AND 2020 BY COUNTIES

D. MUNICIPAL AND INDUSTRIAL WATER USE PROJECTIONS
   HISTORICAL MUNICIPAL WATER USE
E. POPULATION PROJECTIONS JUNE 13, 1972
   1. FINAL NON-ROUNDED PROJECTIONS DECEMBER 1972
F. SURFACE WATER IRRIGATION USE
G. 1. PRINTOUT OF AN INVENTORY OF WATER ORIENTED DATA IN THE COLORADO RIVER BASIN
   2. REPORT ON GROUND WATER AVAILABILITY
H. QUALITY DATA FOR WASTEWATER POINT SOURCES DATA-FILE (OPT FOR AE
I. RAILROAD COMMISSION REPORT ON OIL FIELD BRINES
J. AREAS SUBJECT TO FLOODING
K. SALT WATER POLLUTION OF THE COLORADO RIVER, COLORADO MUN. WATER DIST., JAN 61
L. PROPOSED WATER RESOURCE DEVELOPMENT IN THE COLORADO RIVER BASIN, TWDB, JULY 1966
M. MILEAGES ALONG COLORADO RIVER
   1. PEDERNALES RIVER
   2. LLANO RIVER
   3. CONCHO RIVER
   4. NORTH CONCHO RIVER
   5. BEALS CREEK

TEXAS COUNTY STATISTICS
A. 1968 AGRICULTURAL STATISTICS
B. 1969 AGRICULTURAL STATISTICS

CAPITAL AREA PLANNING COUNCIL-PRELIMINARY LAND USE FORECAST
A. STUDY DESIGN - MAY 1972
B. PRELIM. ENG. REPT., S.T.P., FAYETTVILLE, TEXAS
C. OVERALL ECONOMIC DEVELOPMENT PROGRAM-BASTROP COUNTY JUNE 72

CITY OF AUSTIN
A. QUESTIONAIRE AND FLOW RECORDS
B. CAPITAL IMPROVEMENT PROGRAMS - 1972-1977
C. CENSUS OF HOUSING AND POPULATION
D. WASTEWATER COLLECTION SYSTEM, PHASE 1, OCT 69
E. WASTEWATER TREATMENT WALNUT CREEK SITE

GENERAL HIGHWAY MAPS

IBM DATA SEWAGE TREATMENT PLANT INVENTORY - TWO COPIES

LAND DISPOSAL REPORTS
A. AN OVERLAND FLOW SPRAY IRRIGATION SYSTEM FOR THE TREATMENT OF CANNERY WASTES
B. OWNERSHIP-MANAGERIAL ALTERNATIVES FOR LAND TREATMENT SYSTEMS, JULY 31, 1972
C. WASTEWATER MANAGEMENT BY DISPOSAL ON LAND CRREL LAB REPORT SR171, MAY, 1972
D. SPRAY IRRIGATION MANUAL, PENN. DEPT. OF ENVIRO. RESOURCES NO.31
E. RECYCLING SEWAGE EFFLUENT THROUGH THE SOIL AND

ITS ASSORTED BIOSYSTEMS, PENN. STATE UNIV., REPRINT SERIES 29

F. AGRICULTURAL UTILIZATION OF WASTEWATER EFFLUENTS

G. ASSESSMENT OF THE EFFECTIVENESS AND EFFECTS OF LAND DISPOSAL METHODOLOGIES OF WASTEWATER MANAGEMENT, JAN 72

H. NUTRIENT REMOVAL FROM CANNERY WASTES BY SPRAY IRRIGATION OF GRASSLAND, NOV 69

I. AGRICULTURAL UTILIZATION OF SEWAGE EFFLUENT AND SLUDGE JAN 68

J. ENGINEERING FEASIBILITY DEMO. STUDY FOR MUSKEGON CO. MICH.
   1. DETAILED WORK PROGRAM AND SPECIAL CONDITIONS
   2. ENVIRONMENTAL ASSESSMENT REPORT
   3. WASTEWATER MANAGEMENT, A NEW VISION FOR THE ENVIRONMENT
   4. DR. LOEHR CRITIQUE AND DR. SCHAFFERS ARTICLE
   IRRIGATION SYSTEM SEPT 70

K. C-SELM WASTEWATER MANAGEMENT SURVEY STUDY, PHASE I
   1. TASK NO. 15, SOIL PROCESS, FEB 72
   2. TASK NO. 16, IRRIGATION IMPACT ON AGRICULTURE, FEB 72
   3. TASK NO. 21, UNIT COSTS AND PERFORMANCE, FEB 72

L. FEEDLOT RUNOFF DISPOSAL ON GRASS OR CROPS, TEXAS A&M UNIV 8-72

M. WASTE DISPOSAL ON FARMLAND, USDA, SCS, NOV 68

N. WASTES IN RELATION TO AGRICULTURE AND FORESTRY, USDA PUB. NO. 1065, MAR 68

O. RECYCLING TREATED MUNICIPAL WASTEWATER AND SLUDGE THROUGH FOREST AND CROPLAND, SYMPOSIUM ABSTRACTS UNIV. PARK, PENN. AUG 72

P. A NEW PROSPECT, PREVENTING EUTROPHICATION OF OUR LAKES AND STREAMS, PENN. STATE UNIV., NO. 12, 1970

Q. EFFECTS OF TREES AND FORESTS IN NEUTRALIZING WASTE PENN STATE UNIV., MAR 71
   1. ENVIRONMENTAL PROTECTION CRITERIA FOR DISPOSAL OF TREATED SEWAGE ON FOREST LANDS, US FOREST SERVICE

R. USE OF SEWAGE EFFLUENT FOR PRODUCTION OF AGRICULTURAL CROPS, TWDB, REPT NO.9, DEC 1965

S. HYDROLOGY OF SPRAY-RUNOFF WASTEWATER TREATMENT, ASCE, OCT 1969

T. CANNERY WASTEWATER TREATMENT BY HIGH-RATE SPRAY ON GRASSLAND, JNL. WPCF, SEPT 1970

U. DEGRADATION OF WASTEWATER ORGANICS IN SOIL JNL. WPCF, MAY 1969

V. IRRIGATED PASTURE FOR DISPOSAL OF SECONDARY SEWAGE EFFLUENT

W. INVENTORY OF MUNICIPAL WASTE FACILITIES UTILIZING IRRIGATION

X. NEW INNOVATION IN WASTEWATER TREATMENT

Y. LAND TREATMENT OF WASTEWATER SOME CONSIDERATIONS FOR LAND USE PLANNING, WPCF, OCT 72

Z. DISPOSAL OF DOMESTIC WASTEWATER BY HILLSIDE SPRAYS. JNL EED

CENTRAL TEXAS COUNCIL OF GOVERNMENTS
   A. POPULATION PROJECTIONS

BACTERIOLOGICAL SURVEYANCE COLORADO RIVER TSDH

WATER QUALITY MANAGEMENT STUDY - GUADALUPE RIVER BASIN

A. REPT. NO. 3 - ECONOMIC PROJECTIONS
B. REPT. NO. 5 - CONCEPT. PLAN FOR REGIONAL WASTEWATER TREAT.
C. REPT. NO. 7 - JURISDICTIONAL & FINANCIAL CONCEPTS OF REGIONAL WASTEWATER MANAGEMENT

WASTEWATER MANAGEMENT NEWSLETTER

STATE AND FIELD SUPERVISORY PERSONNEL LIST-TEXAS, USDA,FHA, T.I.015.2A

TWQB - SPECIAL REPORTS AND DOCUMENTS

A. MUNICIPAL WATER POLLUTION CONTROL AND ABATEMENT PROGRAM
B. A SUGGESTED INDUSTRIAL WASTE ORDINANCE NO.72-04
C. CITIES WITH MUNICIPAL WATER POLLUTION CONTROL PROGRAMS
D. MUNICIPAL / INDUSTRIAL RETURN FLOW
E. WATER QUALITY BOARD MONITORING STATIONS
F. WATER QUALITY STANDARDS SUMMARY, SEPT 1969, APRIL 1972
G. WATER QUALITY REQUIREMENTS, VOL. 1, INLAND WATERS, JUNE 1967
H. INSTRUCTIONS FOR TWQB. PRINT-OUT
J. SUBSURFACE WASTE DISPOSAL IN TEXAS, PUB. 72-05
K. DISCHARGERS IN TRAVIS COUNTY
L. FIELD REPORTS
   1. GIDDINGS
   2. BURNETT
   3. GOLDTHWAITE
   4. MARBLE FALLS
   5. CAPITOL AGGREGATES
   6. BANES ISD
   7. POINT VENTURE
   8. MANOR
   9. DEVELOPMENT ASSOCIATES
   10. COUNTRY AIR
   11. SCENIC BROOK WEST
M. SPECIAL DATA
   1. ZONES OF SIGNIFICANT NON-COMPLIANCE
   2. COMPLIANT ZONES TO BE ENHANCED DURING FY 73
   3. POLLUTION CONTROL FACILITIES TO BE PLACED IN OPERATION
   4. DISCHARGERS TO BE BROUGHT INTO COMPLIANCE
N. TWQB DISTRICT NO. 6 DATA
   1. SECTION 1 - CONTINUING STUDY OF THE COLORADO RIVER
   2. SECTION 2 - CONCHO RIVER STUDY
   3. SECTION 3 - ELM CREEK AND TRIBUTARIES

TEXAS CONSERVATION NEEDS INVENTORY 1970

PUBLICATIONS OF THE ENVIRONMENTAL PROTECTION AGENCY

A. GUIDELINES WATER QUALITY MANAGEMENT PLANNING
B. TECHNOLOGY TRANSFER, PROCESS DESIGN MANUALS
   1. CARBON ADSORPTION
   2. PHOSPHORUS REMOVAL
   3. UPGRADING EXISTING PLANTS
   4. SUSPENDED SOLIDS REMOVAL

C. MUNICIPAL WASTE FACILITIES, 1968 INVENTORY
D. WATER POLLUTION CONTROL RESEARCH SERIES
 1. COMBINED SEWER OVERFLOW ABATEMENT ALTERNATIVES
 2. HYPOCHLORITE GENERATOR FOR TREATMENT OF COMBINED SEWER OVERFLOWS
 3. IMPREGNATION OF CONCRETE PIPE
 4. SELECTED URBAN STORM WATER RUN-OFF ABSTRACTS 11024EJC
 5. SELECTED URBAN STORM WATER RUN-OFF ABSTRACTS 11024FJE
 6. SEWER BEDDING AND INFILTRATION GULF COAST AREA
 7. STORM WATER PROBLEMS AND CONTROL IN SANITARY SEWERS
 8. URBAN RUN-OFF CHARACTERISTICS
 9. URBAN RUN-OFF AND COMBINED SEWER OVERFLOW POLLUTION
 10. STORM AND COMBINED SEWER POLLUTION SOURCES AND ABATEMENT
 11. BIBLIOGRAPHY OF WQ RESEARCH PROJECT REPORTS, SEPT 1971
 12. DESIGN GUIDES FOR BIOLOGICAL WASTEWATER TREATMENT PROCESSES
 13. ESTIMATING COSTS AND MANPOWER REQUIREMENTS FOR CONVENTIONAL WASTEWATER TREATMENT FACILITIES
E. RIVER BASIN SIMULATION PROGRAM, FWPCA
F. HEALTH GUIDELINES FOR WATER AND RELATED LAND RESOURCES PLANNING, DEVELOPMENT, AND MANAGEMENT
G. CHARACTERISTICS OF WASTES FROM SOUTHWESTERN CATTLE FEEDLOTS
H. EVALUATION OF BEEF CATTLE FEEDLOT WASTE MANAGEMENT ALTERNATIVES
I. ANIMAL FEEDLOT WASTE RESEARCH PROGRAM, APRIL 1971
J. THE UTILIZATION OF LAND FOR SEWAGE DISPOSAL ABSTRACTED FROM 68 INVENTORY MUNICIPAL WASTE FACILITIES

WASTEWATER MANAGEMENT STUDY, COLORADO RIVER AND TRIBUTARIES, TEXAS PLAN OF STUDY, 15 FEB 72

A STUDY OF COSTS FOR REUSING MUNICIPAL WASTE RETURN FLOWS IN SELECTED TEXAS CITIES, TWDB
A. VOLS I AND II - CORPUS CHRISTI
B. VOLS I AND III- EL PASO
C. VOLS I AND IV - MIDLAND
D. VOLS I AND V - SAN ANGELO
E. VOLS I AND VI - SAN ANTONIO

TWDB - SPECIAL REPORTS AND DOCUMENTS
A. REPORT 3 - HYDROLOGIC STUDIES OF SMALL WATERSHEDS, DEEP CREEK
B. REPORT 6 - HYDROLOGIC STUDIES OF SMALL WATERSHEDS, MUKEWATER CR
C. REPORT 8 - REUSE OF EFFLUENT IN THE FUTURE, BIBLIOGRAPHY,DEC.65
D. REPT. 71 - RECONNAISSANCE OF THE CHEMICAL QUALITY OF SURFACE WATERS OF THE COLO. RIVER BASIN, MAR 1968
E. REPT. 108 - BOD, DO, SELECTED NUTRIENTS, AND PESTICIDE RECORDS OF TEXAS SURFACE WATERS,1968, FEB 1970
F. CATALOGUE OF WATER ORIENTED DATA
 1. VOL 13-BRAZOS-COLORADO COASTAL BASIN
 2. VOL 14-COLORADO RIVER BASIN
 3. VOL 15-COLORADO-LAVACA COASTAL BASIN
G. RECONNAISSANCE INVESTIGATION OF THE GROUND WATER RESOURCES OF THE COLORADO RIVER BASIN

H. GROUND WATER QUALITY
I. WATER QUALITY RECORDS FOR SELECTED RESERVOIRS IN
   TEXAS AND ADJOINING AREAS. APR.1965 - SEP.1969, 2 COPIES
J. SIMULATION OF WATER QUALITY IN STREAMS AND CANALS. REPORT 128
   1. THEORY AND DESCRIPTION
   2. DOSAG - 1
   3. QUAL - 1
K. INVENTORIES OF IRRIGATION IN TEXAS, REPORT 127
   YEARS 1958, 1964, AND 1969
L. WATER REQUIREMENTS SURVEY FOR TEXAS, JULY 1959

GOLDTHWAITE - ENGINEERING REPORT

USDA, SCS, SOIL SURVEYS
A. GAINES CO., JUNE 1965
B. DAWSON CO., AUG 1960
C. MITCHELL CO., APR 1969 (2 COPIES)
D. HOWARD CO., MAR 1969
E. EXHIBIT SHOWING ADEQUACY OF SOIL SURVEYS FOR OPER. PLANNING
F. EXHIBIT SHOWING SOIL AND WATER CONSERV. DISTRICTS + WORK UNITS
G. HOCKLEY CO., 1965
H. COCHRAN CO., 1964
I. MENARD CO., 1967
J. LYNN CO., 1959
K. SUTTON CO., 1968
L. TERRY CO., 1962
M. YOAKUM CO., 1964
N. RUNNELS CO., 1970
O. GUIDE FOR INTERPRETING ENGINEERING USES OF SOILS, SCS, 1971
P. DETAIL SOIL DATA
   1. ACME THRU CLAIREMONT SERIES
   2. CLAIREMONT THRU HARLINGEN SERIES
   3. HARLINGEN THRU NEWTONIA SERIES
   4. NEWTONIA THRU SPIRO SERIES
   5. SPIRO THRU ZITA SERIES

USGS GAGING STATION DESCRIPTIONS

BUREAU OF ECONOMIC GEOLOGY, UNIV. OF TEXAS
A. GEOLOGIC ATLASES OF TEXAS

U.S. DEPT. OF COMMERCE CLEARINGHOUSE - SPECIAL REPORTS
A. DISPOSAL OF WASTES FROM WTPS
B. HYDRAULIC ASPECTS OF FEEDLOT WASTE CONTROL
C. THE IDENTIFICATION AND CRITICAL ANALYSIS OF SELECTED LITERATURE
   DEALING WITH THE RECREAT. ASPECTS OF WATER RESOURCE USE,
   PLANNING AND DEVELOPMENT
D. PHYSICAL AND ECONOMIC FACTORS ASSOC. WITH THE ESTAB. OF
   STREAM WATER QUALITY STANDARDS
E. THE RELATIONSHIP BETWEEN LAND VALUES AND FLOOD
   RISK IN THE WABASH RIVER BASIN

F. SELECTED BIBLIOGRAPHY ON THE ANALYSIS OF WATER RESOURCE SYSTEMS

UNIVERSITY OF TEXAS - SPECIAL REPORTS
- A. MANAGEMENT OF RETURN FLOWS IN TEXAS
- B. A NETWORK FLOW ANALYSIS OF WATER ALLOCATION DECISIONS IN A RIVER SYSTEM AND THEIR EFFECTS ON ESTUARINE ECOLOGY
- C. NUMERICAL SIMULATION OF WATERSHED HYDROLOGY
- D. NUMERICAL SIMULATION OF WATERSHED AS A MEANS TO EVALUATE SOME EFFECTS OF FLOOD WATER RETARD. STRUCTURES ON RUN-OFF
- E. SEMINAR ON MANAGEMENT OF RIVER BASINS, APR 1965
- F. SIMULATION OF STREAM PROCESSES IN A MODEL RIVER
- G. EFFLUENT QUALITY AND TREATMENT ECONOMICS FOR INDUSTRIAL WASTEWATERS

WATER RESOURCES RESEARCH
- A. VOLUME NO. 7
  - 1. NO. 1 FEB 71
  - 2. NO. 2 APR 71
  - 3. NO. 3 JUN 71
  - 4. NO. 4 AUG 71
  - 5. NO. 5 OCT 71
  - 6. NO. 6 DEC 71
- B. VOLUME NO. 8
  - 1. NO. 1 FEB 72
  - 2. NO. 2 APR 72
  - 3. NO. 3 JUN 72
  - 4. NO. 6 DEC 72

ALTERNATIVES FOR MANAGING WASTEWATER
- A. SOUTHEASTERN MICHIGAN
  - 1. SUMM. REPT.
  - 2. APPENDICES
- B. CLEVELAND - AKRON METRO AREA
  - 1. SUMM. REPT.
  - 2. APPENDICES 1 AND 2
  - 3. APPENDIX 3
- C. CHICAGO SOUTH-END LAKE MICHIGAN AREA
  - 1. SUMM. REPT.
  - 2. APPENDICES
- D. SAN FRANCISCO BAY AND SACRAMENTO AREA
  - 1. SUMM. REPT.
  - 2. VOL. 1 - APPEND. A - STUDY AREA TODAY & IN THE FUTURE
APPEND. B - ALTERNATIVES
  - 3. VOL. 2 - APPEND. C - ASSESSMENT OF IMPACTS - SELECTED ALTS.
  - 4. VOL. 3 - APPEND. D - EVAL. OF SELECTED ALTERNATIVES
APPEND E - BIBLIOGRAPHY

THE MERRIMACK - DESIGNS FOR A CLEAN RIVER
- A. ANNEX A - CONSULTANTS LAND AND WATER DISPOSAL ASSESSMENTS
- B. ANNEX B - CONSULTANTS IMPACT ASSESSMENTS
- C. ANNEX C - CONSULTANTS INDUSTRIAL WASTEWATER PROFILES

D. APPEND. 1&2 - INTRODUCTION
E. APPEND. 3 - DEVELOPMENT OF ALTERNATIVES
F. APPEND. 4&5 - ASSESSMENT AND EVAL. OF SELECTED ALTERNATIVES
G. ALTERNATIVES FOR MANAGING WASTEWATER - SUMMARY REPORT

TEXAS TECH UNIV. WATER RESOURCES CENTER - SPECIAL REPORTS
A. CONJUNCTIVE USE OF WATER IN WEST TEXAS
B. ENVIRO. IMPACT ANAL. - SALT RETENT. STRUCT. UPPER BRAZOS BASIN
C. VARIATION OF URBAN RUN-OFF WITH DURATION AND INTENS. OF STORMS

INTERIM BASIN PLAN SABINE RIVER BASIN - SEPT 1971

TEXAS WATER COMMISSION - SPECIAL REPORTS
A. RECONNAISSANCE INVEST. OF THE GROUNDWATER RESOURCES OF THE GULF COAST REGION, BUL. 6305, 2 COPIES

U.S. DEPT. OF COMMERCE / BUREAU OF THE CENSUS
A. GENERAL DEMOGRAPHIC TRENDS FOR METRO. AREAS, 1960 TO 1970
B. 1970 CENSUS OF HOUSING AND POPULATION

WATER QUALITY MANAGEMENT PLANNING FOR THE COLORADO RIVER BASIN
A PRESENTATION TO THE US ARMY ENGINEER DISTRICT

RELATED TEXTBOOKS AND PUBLICATIONS
A. WATER QUALITY CRITERIA
B. WATER QUAL. IMPROV. BY CHEM. & PHYS. PROCESSES
C. IRRIG. OF AGRICULTURAL LANDS
D. IRRIG. PRINCIPLES AND PRACTICES
E. ADVANCES IN ENVIRONMENTAL SERVICES AND TECH.
F. GROUNDWATER RESOURCE EVALUATION
G. WATER AND WATER POLL. HANDBOOK
H. SUBSURFACE DISPOSAL IN GEOLOGIC BASINS
I. SOCIAL AND ECOL. ASPECTS / 1970
J. LAWS OF THE U.S. RELATING TO WATER POLL. & ENVIRO. QUALITY
K. SYSTEM SIMUL. FOR REGIONAL ANAL.
L. STATISTICAL ABSTRACT OF THE US 1971
M. ATLAS OF TEXAS
N. HGAC DOCUMENTS
   1. REGIONAL DATA BOOK VOL 1, 1972
   2. REGIONAL ATLAS, 1972
O. ADVANCED WASTEWATER TREATMENT
P. REGIONAL COUNCILS IN TEXAS, 72 DIRECTORY
Q. TEXAS ALMANAC 1972-1973
R. CONSULTING ENGINEERING, ASCE MANUAL NO. 45
S. SEWAGE TREATMENT PLANT DESIGN
T. DESIGN AND CONSTRUCTION OF SANITARY AND STORM SEWERS WPCF MOP9
U. DESIGN CRITERIA FOR SEWERAGE SYSTEMS

CITY OF BROWNWOOD
A. POPULATION CHARACTERISTICS

1. ENVIRONMENTAL STATEMENT
2. ORIENTATION HANDOUT
B. WATER SYSTEM STUDY, 1964
C. SANITARY SEWER SYSTEM, 1965
D. LAND USE MAP
E. CITY PLAN, 1960
1. SUMMARY REPORT
2. ADMINISTRATION
3. FACILITIES
F. PRESENT AND FUTURE SEWAGE TREATMENT FACILITIES, JULY 51
G. FEASIBILITY STUDY ON EXPANSION OF WASTEWATER TREATMENT PLAN, FEB 71
H. MEMORANDUM REPORT ON THE BROWNWOOD SEWAGE TREATMENT PLANT, JAN 72

CITY OF BIG SPRING
A. PAST PLANNING PROGRESS FUTURE DEVELOPMENT GOALS, JAN 1969
B. WATER AND SANITARY SEWAGE SYSTEM IMPROVEMENTS, MAY 1960
C. STUDY OF WASTEWATER TREATMENT FACILITIES, JULY 71

CITY OF SAN ANGELO
A. TRANSPORTATION PLAN
1. VOL. 1, 1964
2. VOL. 2, 1965-1985
3. PROGRESS REPORT, 1965-1969
B. WASTEWATER ANALYSES

REPORT OF THE U.S. STUDY COMMISSION - TEXAS
A. PART 1 - THE COMMISSION PLAN
B. PART 2 - RESOURCES AND PROBLEMS
C. PART 3 - THE EIGHT BASINS

NEW RESOURCES...TEXAS RESERVOIRS, TX. WATER CONS. ASSN., 1972

RECORDS OF PUBLIC MEETINGS, AUSTIN AND SAN ANGELO

OBJECTIVES OF THE GOVERNORS PLANNING COMMITTEE

INTERIM WATER QUALITY PLAN FOR MERTZON, TEXAS

THE COMPREHENSIVE PLAN FOR CITY OF LEVELLAND

THE CODORUS CREEK WASTEWATER MANAGEMENT STUDY
A. SUMMARY REPORT AND CONCLUSIONS
B. APPENDIX A - TECHNICAL STUDIES
1. VOL. 1
2. VOL. 2
3. VOL. 3
4. VOL. 4
C. APPENDIX B - IMPACT STUDIES
D. APPENDIX C - ANALYSIS OF INSTITUTIONAL ARRANGEMENTS

E. APPENDIX C SUPPLEMENT - IMPLEMENTATION

SOUTH PLAINS COUNCIL OF GOVERNMENTS
- A. SOLID WASTE MANAGEMENT
- B. REGIONAL PARKS AND OPEN SPACE PLAN
- C. REG. LAND USAGE AND RESOURCE MANAGEMENT PLAN

CITY OF SEAGRAVES - THE SEAGRAVES PLAN
- A. LAND USE AND NEIGHBORHOOD ANALYSIS
- B. POPULATION AND ECONOMY
- C. THOROUGHFARES, COMMUNITY FACILITIES - WATER, SEWER, AND DRAINAGE
- D. CAPITAL IMPROVEMENT PROGRAM
- E. ZONING, LAND SUBDIVISION AND ADMINISTRATION
- F. COMPREHENSIVE REPORT

MISCELLANEOUS CITIES
- A. SANITARY SEWAGE FACILITIES STUDY - CITY OF SMITHVILLE
- B. CITY OF SMITHVILLE SANITARY SEWAGE FACILITIES STUDY
- C. CITY OF GOLDTHWAITE SEWAGE TREATMENT PLANT AND OUTFALL SEWER, ENGINEERING REPORT
- D. CITY OF WINTERS
  - 1. WASTEWATER TREATMENT STUDY 1972
  - 2. COMPREHENSIVE PLAN
  - 3. COMMUNITY APPEARANCE
  - 4. COMMUNITY FACILITIES
  - 5. LAND USE
  - 6. BASE STUDIES
  - 7. UTILITIES AND DRAINAGE
  - 8. CAPITAL IMPROVEMENTS PROGRAM
- E. COLORADO CITY COMPREHENSIVE PLAN-UTILITIES AND DRAINAGE (PARTIAL COPY, SEPT 70)
- F. SPRINKLER IRRIGATION DESIGN USING SEWAGE EFFLUENT - CITY OF MILES
- G. WASTEWATER TREATMENT PLANT, CITY OF BANGS, AUG 72
- H. WASTEWATER TREATMENT PLANT, CITY OF COLEMAN, JUNE 69
- I. A COMPREHENSIVE PLAN, SUNDOWN, TEXAS

WASTEWATER TREATMENT COST MODELS AND REQUIRED PARAMETERS JULY 71

INDUSTRIAL WATER ENGINEERING, VOL 9 NO 4, JUNE-JULY 72

US DEPT. OF COMMERCE NTIS REPORTS
- A. SEWAGE SLUDGE INCINERATION
- B. ECONOMIC VALUE OF WATER IN A SYSTEMS CONTEXT, MAY 72
- C. PROCEEDINGS - URBAN RAINFALL MANAGEMENT PROBLEMS
- D. FEEDLOT WASTE MANAGEMENT WHY AND HOW
- E. SUBSURFACE WATER POLLUTION, A SELECTIVE BIBLIOGRAPHY
- F. A COMPUTER MODEL FOR PREDICTING NITRATE AND OTHER SOLUTES OF AGRICULTURAL DRAIN WATER
- G. A REVIEW OF ON-SITE DOMESTIC SEWAGE TREATMENT

FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972, SEPTEMBER 28, 1972

WATER QUALITY MANAGEMENT PLANS, PREPARATION GUIDELINES FOR STATES, ENVIRONMENTAL PROTECTION AGENCY, 40 CFR PART 131, VOL. 38 NO. 99, MAY 23, 1973

VI. GLOSSARY OF TERMS AND ABBREVIATIONS

General

This section of the Appendix constitutes a glossary of terms, processes, units, and methods used in the Colorado River Basin Wastewater Management Study and a listing of the commonly-used abbreviations. Not all terms appear here, but an attempt was made to present the more technical ones used by engineers and scientists in the water distribution, collection, treatment, disposal, and reuse field. Similarly, not all terms which appear here are found in the text of the report, but those which are synonymous or which further describe another term were included.

This glossary of terms was derived from "Glossary - Water and Wastewater Control Engineering," prepared by joint Editorial Board represesenting A.P.H.A., A.S.C.E., A.W.W.A., and W.P.C.F., 1969.

TABLE VI-1

ABBREVIATIONS

ac.	acres
ac-ft.	acre-feet
cfs	cubic feet per second
F. M.	force main
ft.	feet
gpd	gallons per day
gpm	gallons per minute
in.	inches
L. S.	lift station
mgd, MGD	million gallons per day
mg/l	milligrams per liter
ppd	pounds per day
ppm	parts per million
P. S.	pump station
sq. ft.	square feet
S. T. P.	sewage treatment plant

TABLE VI-2

GLOSSARY OF TERMS

abandonment - A legal term used to designate the giving up, with the definite intent to do so, of the right to use water for any purpose, or the method of using such water. A temporary cessation of such use or temporary giving up of such right does not constitute abandonment. Intent to abandon may be implied from acts of the one using the water, such as nonuse for a considerable period or diversion without beneficial use.

absorption - The taking up of one substance into the body of another.

acre-foot - (1) A volume of water 1 ft. deep and 1 acre in area, or 43,560 cu. ft. (2) A 43,560-cu. ft. volume of trickling filter medium.

activated carbon - Carbon particles usually obtained by carbonization of cellulosic material in the absence of air and possessing a high adsorptive capacity.

activated sludge - Sludge floc produced in raw or settled wastewater by the growth of zoogleal bacteria and other organisms in the presence of dissolved oxygen and accumulated in sufficient concentration by returning floc previously formed.

activated sludge process - A biological wastewater treatment process in which a mixture of wastewater and activated sludge is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater (mixed liquor) by sedimentation and wasted or returned to the process as needed.

adsorption - The adherence of a gas, liquid, or dissolved material on the surface of a solid.

aerated pond - A natural or artificial wastewater treatment pond in which mechanical or diffused-air aeration is used to supplement the oxygen supply.

aeration - The bringing about of intimate contact between air and a liquid by one or more of the following methods: (a) spraying the liquid in the air, (b) bubbling air through the liquid, (c) agitating the liquid to promote surface absorption of air.

aerobic - Requiring, or not destroyed by, the presence of free elemental oxygen.

aerobic digestion - Digestion of suspended organic matter by means of aeration.

algae - Primitive plants, one or many-celled, usually aquatic, and capable of elaborating their foodstuffs by photosynthesis.

algae bloom - Large masses of microscopic and macroscopic plant life, such as green algae, occurring in bodies of water.

alum - A common name, in the water and wastewater treatment field, for commercial-grade aluminum sulfate.

aluminum sulfate- A chemical, formerly sometimes called "waterworks alum" in water or wastewater treatment, prepared by combining a mineral known as bauxite with sulfuric acid.

anaerobic - Requiring, or not destroyed by, the absence of air or free oxygen.

anaerobic waste treatment - Waste stabilization brought about through the action of microorganisms in the absence of air or elemental oxygen. Usually refers to waste treatment by methane fermentation.

aquifer - A porous, water-bearing geologic formation. Generally restricted to materials capable of yielding an appreciable supply of water.

arable area - In irrigation, all lands which have sufficient potential for sustained productivity to warrant consideration for irrigation development.

arid - A term applied to regions where precipitation is so deficient in quantity, or occurs at such times, that agriculture is impracticable without irrigation.

assimilative capacity - The capacity of a natural body of water to receive: (a) wastewaters, without deleterious effects; (b) toxic materials, without damage to aquatic life or humans who consume the water; (c) BOD, within prescribed dissolved oxygen limits.

back wash - The reversal of flow through a rapid sand filter to wash clogging material out of the filtering medium and reduce conditions causing loss of head. Also called filter wash.

backwashing - The operation of cleaning a filter by reversing the flow of liquid through it and washing out matter previously captured in it. Filters would include true filters such as sand and diatomaceous-earth types but not other treatment units such as trickling filters.

bacteria - A group of universally distributed, rigid, essentially unicellular microscopic organisms lacking chlorophyll. Bacteria usually appear as spheroid, rod-like, or curved entities, but occasionally appear as sheets, chains, or branched filaments. Bacteria are usually regarded as plants.

bar rack - A screen composed of parallel bars, either vertical or inclined, placed in a waterway to catch debris. The screenings may be raked from it. Also called rack.

base flow - That part of the stream discharge that is not attributable to direct runoff from precipitation or melting snow; it is usually sustained by water draining from natural storage in groundwater bodies, lakes, or swamps.

basin - (1) A natural or artificially created space or structure, surface or underground, which has a shape and character of confining material that enable it to hold water. The term is sometimes used for a receptacle midway in size between a reservoir and a tank. (2) The surface area within a given drainage system. (3) A shallow tank or depression through which liquids may be passed or in which they are detained for treatment or storage.

bedrock - The solid rock encountered below the mantle of loose rock and more or less unconsolidated material which occurs on the surface of the lithosphere. In many places, bedrock appears at the surface.

biochemical oxygen demand - A standard test used in assessing wastewater strength.

biological process - The process by which the life activities of bacteria and other microorganisms in the search for food, break down complex organic materials into simple, more stable substances. Self-purification of polluted streams, sludge digestion, and all the so-called secondary wastewater treatments result from this process.

biological wastewater treatment - Forms of wastewater treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Intermittent sand filters, contact beds, trickling filters, and activated sludge processes are examples.

BOD - (1) Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) A standard test used in assessing wastewater strength.

BOD Load - The BOD content, usually expressed in pounds per unit of time, of wastewater passing into a waste treatment system or to a body of water.

brackish water - Water having a mineral content in the general range between fresh water and seawater. Water containing from 1,000 to 10,000 mg/1 of dissolved solids.

brine - Concentrated salt solution remaining after removal of distilled product; also, concentrated brackish saline or sea waters containing more than 36,000 mg/1 of total dissolved solids.

broad irrigation - The irrigation of crops with wastewater. It differs from wastewater irrigation in that wastewater disposal is the primary object of broad irrigation and the raising of crops is incidental.

bypass - An arrangement of pipes, conduits, gates, and valves whereby the flow may be passed around a hydraulic structure or appurtenance.

caliche - A hard deposit, consisting mostly of calcium carbonate or of gravel and sand cemented by calcium carbonate, found in the subsoil in arid sections. The deposit may range from several inches to several feet in thickness, and is presumed to have been created by the evaporation of mineral-laden capillary water, leaving a residue that served as a cementing material. Also, crude sodium nitrate in Chilean deposits.

carbonation - The diffusion of carbon dioxide gas through a liquid to render the liquid stable with respect to precipitation or dissolution of alkaline constituents.

cesspool - A lined or partially lined underground pit into which raw household wastewater is discharged and from which the liquid seeps into the surrounding soil. Sometimes called leaching cesspool.

chemical coagulation - The destablization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical.

chemical oxygen demand (COD) - A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It is expressed as the amount of oxygen consumed from a chemical oxidant in a specific test. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand. Also known as OC and DOC, oxygen consumed and dichromate oxygen consumed, respectively.

chemical precipitation - Precipitation induced by addition of chemicals.

chlorination - The application of chlorine to water or wastewater, generally for the purpose of disinfection, but frequently for accomplishing other biological or chemical results.

chlorination chamber - A detention basin provided primarily to secure the diffusion of chlorine through the liquid. Also called chlorine contact chamber.

clarification - Any process or combination of processes the primary purpose of which is to reduce the concentration of suspended matter in a liquid.

clarifier - A unit of which the primary purpose is to secure clarification. Usually applied to sedimentation tanks or basins.

climate - The total of meteorological phenomena which combine to characterize the average and extreme condition of the atmosphere at any specified place on the earth's surface.

coagulant - A compound responsible for coagulation; a floc-forming agent.

coagulation - In water and wastewater treatment, the destabilization and initial aggregation of colloidal and finely divided suspended matter by the addition of a floc-forming chemical or by biological processes.

coliform-group bacteria - A group of bacteria predominantly inhabiting the intestines of man or animal, but also occasionally found elsewhere.

combined sewer - A sewer intended to receive both wastewater and storm or surface water.

comminution - The process of cutting and screening solids contained in wastewater flow before it enters the flow pumps or other units in the treatment plant.

complete diversion - The taking or removing of water from one location in a natural drainage area and the discharge of it into another drainage area.

concentration - (1) The amount of a given substance dissolved in a unit volume of solution. (2) The process of increasing the dissolved solids per unit volume of solution, usually by evaporation of the liquid.

confluence - A junction or flowing together of streams; the place where streams meet.

conservation storage - Storage of water for future useful purposes such as municipal supply, power, or irrigation.

consumer - A household, building, institution, mercantile establishment, industrial plant, or other user receiving water through a service pipe. Large consumers may have two or more service pipes.

contact aerator - A biological unit consisting of stone, cement-asbestos, or other surfaces supported in an aeration tank, in which air is diffused up and around the surfaces and settled wastewater flows through the tank.

contact stabilization process - A modification of the activated sludge process in which raw wastewater is aerated with a high concentration of activated sludge for a short period, usually less than 60 min, to obtain BOD removal by absorption. The solids are subsequently removed by sedimentation and transferred to a stabilization tank where aeration is continued further to oxidize and condition them before their reintroduction to the raw wastewater flow.

contamination - Any introduction into water of microorganisms, chemicals, wastes, or wastewater in a concentration that makes the water unfit for its intended use.

cooling tower - A hollow, vertical structure with internal baffles to break up falling water so that it is cooled by upward-flowing air and by evaporation of water.

cropland - Land regularly used for the production of crops.

cubic foot per second (cfs) - A unit of measure of the rate of liquid flow past a given point equal to one cubic foot in one second. Previously also called second-foot.

data - Records of observations and measurements of physical facts, occurrences, and conditions, reduced to written, graphical, or tabular form.

degree of treatment - A measure of the removal effected by treatment processes with reference to solids, organic matter, BOD, bacteria, or any other specified matter.

detention tank - A tank used in water or wastewater treatment to provide adequate time for chemical or physical reactions to take place in the body of liquid being treated.

detention time - The theoretical time required to displace the contents of a tank or unit at a given rate of discharge (volume divided by rate of discharge).

diffused-air aeration - Aeration produced in a liquid by air passed through a diffuser.

digested sludge - Sludge digested under either aerobic or anaerobic conditions until the volatile content has been reduced to the point at which the solids are relatively nonputrescible and inoffensive.

digester - A tank in which sludge is placed to permit digestion to occur. Also called sludge digestion tank.

digestion - (1) The biological decomposition of organic matter in sludge, resulting in partial gasification, liquefaction, and mineralization. (2) The process carried out in a digester.

dilution - Disposal of wastewater or treated effluent by discharging it into a stream or body of water.

direct irrigation - Application of wastewater directly to land by spraying, multiple outlet pipes, or furrows for the purpose of disposing of wastewater rather than raising crops.

direct runoff - The runoff that enters stream channels promptly by flow over the ground surface or through the ground without entering the main water table, or that portion of the runoff which is directly associated with causative rainfall or snow melt.

discharge - (1) As applied to a stream or conduit, the rate of flow, or volume of water flowing in the stream or conduit at a given place and within a given period of time. (2) The rate of flow of water which passes along a conduit or channel, usually expressed as cubic feet per second, gallons per minute, or million gallons per day.

disinfection - The art of killing the larger portion of microorganisms in or on a substance with the probability that all pathogenic bacteria are killed by the agent used.

dissolved oxygen - The oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million or percent of saturation. Abbreviated DO.

dissolved-oxygen sag curve - A curve that represents the profile of dissolved oxygen content along the course of a stream resulting from deoxygenation associated with biochemical oxidation of organic matter and reoxygenation through the absorption of atmospheric oxygen and biological photosynthesis. Also called oxygen-sag curve.

dissolved solids - Theoretically, the anhydrous residues of the dissolved constituents in water.

ditch oxidation - A modification of the activated sludge process or the aerated pond, in which the mixture under treatment is circulated in an endless ditch and aeration and circulation are produced by a mechanical device such as a Kessener brush.

diversion - The taking of water from a stream or other body of surface water into a canal, pipeline, or other conduit.

domestic wastewater - Wastewater derived principally from dwellings, business buildings, institutions, and the like. It may or may not contain ground water, surface water, or storm water.

drain tile - Pipes of various materials, in short lengths, laid in covered trenches underground, in most cases quite loosely and with open joints, to collect and carry off excess groundwater or to dispose of wastewater in the ground. Agricultural drain is ordinarily made with plain ends.

Dunbar filter - A type of trickling filter, originated by Dunbar in 1901, with a fine top layer (coarse sand) and successive lower layers of broken stone, with the coarsest stone on the bottom. Rarely used.

effluent - Wastewater or other liquid, partially or completely treated, or in its natural state, flowing out of a reservoir, basin, treatment plant, or industrial treatment plant, or part thereof.

equalizing basin - A holding basin in which variations in flow and composition of a liquid are averaged. Such basins are used to provide a flow of reasonably uniform volume and composition to a treatment unit. Also called balancing reservoir.

Escherichia coli (E. coli) - One of the species of bacteria in the coliform group. Its presence is considered indicative of fresh fecal contamination.

estuary - A passage in which the tide meets a river current; especially an arm of the sea at the lower end of a river; a firth.

eutrophic lake - Lake or other contained water body rich in nutrient. Characterized by a large quantity of planktonic algae, low water transparency with high dissolved oxygen in upper layer, zero dissolved oxygen in deep layers during summer months, and large organic deposits colored brown or black. Hydrogen sulfide often present in water and deposits.

evaporation - The process by which water becomes a vapor at a temperature below the boiling point.

evaporation pan - A pan used to hold water during observations for the determination of the quantity of evaporation at a given location. Such pans are of various sizes and shapes, the most commonly used being circular or square.

evaporation rate - The quantity of water, expressed in terms of depth of liquid water, evaporated from a given water surface per unit of time. It is usually expressed in inches depth per day, month, or year.

excess sludge - The sludge produced in an activated sludge treatment plant that is not needed to maintain the process and is withdrawn from circulation.

extended aeration - A modification of the activated sludge process which provides for aerobic sludge digestion within the aeration system. The concept envisages the stabilization of organic matter under aerobic conditions and disposal of the end products into the air as gases and with the plant effluent as finely divided suspended matter and soluble matter.

filter - A device or structure for removing solid or colloidal material, usually of a type that cannot be removed by sedimentation, from water, wastewater, or other liquid. The liquid is passed through a filtering medium, usually a grándular material but sometimes finely woven cloth, unglazed porcelain, or specially prepared paper. There are many types of filters used in water or wastewater treatment.

filter loading - Organically, the pounds of biochemical oxygen demand (BOD) in the applied liquid per unit of filter bed area or volume per day. Hydraulically, the quantity of liquid applied per unit of filter bed area or volume per day.

final effluent - The effluent from the final treatment unit of a wastewater treatment plant.

final sedimentation - The separation of solids from wastewater in a final settling tank.

five-day BOD - That part of oxygen demand associated with biochemical oxidation of carbonaceous, as distinct from nitrogeneous, material. It is determined by allowing biochemical oxidation to proceed, under conditions specified in Standard Methods, for 5 days.

flocculation - In water and wastewater treatment, the agglomeration of colloidal and finely divided suspended matter after coagulation by gentle stirring by either mechanical or hydraulic means. In biological wastewater treatment where coagulation is not used, agglomeration may be accomplished biologically.

flotation - The raising of suspended matter to the surface of the liquid in a tank as scum-by aeration, the evolution of gas, chemicals, electrolysis heat, or bacterial decomposition - and the subsequent removal of the scum by skimming.

flow - The movement of a stream of water or other mobile substance from place to place; a stream of water; movement of silt, water, sand or other material.

force main - A pressure pipe joining the pump discharge at a water or wastewater pumping station with a point of gravity flow.

gaging station - A location on a stream or conduit where measurements of discharge are customarily made. The location includes a stretch of channel through which the flow is uniform and a control downstream from this stretch. The station usually has a recording or other gage for measuring the elevation of the water surface in the channel or conduit.

grade - The inclination or slope of a stream channel, conduit, or natural ground surface, usually expressed in terms of the ratio or percentage of number of units of verticle rise or fall per unit of horizontal distance. Also see slope.

grit chamber - A detention chamber or an enlargement of a sewer designed to reduce the velocity of flow of the liquid to permit the separation of mineral from organic solids by differential sedimentation.

ground water - Subsurface water occupying the saturation zone, from which wells and springs are fed. In a strict sense the term applies only to water below the water table. Also called phreatic water, plerotic water.

heavy metals - Metals that can be precipitated by hydrogen sulfide in acid solution, for example, lead, silver, gold, mercury, bismuth, copper.

high-rate filter - A trickling filter operated at a high average daily dosing rate, usually between 10 and 40 mgd/acre including any recirculation of effluent.

hydrated lime - Limestone that has been "burned" and treated with water under controlled conditions until the calcium oxide portion has been converted to calcium hydroxide.

Imhoff tank - A deep, two-storied wastewater tank originally patented by Karl Imhoff. It consists of an upper continuous-flow sedimentation chamber and a lower sludge-digestion chamber. The floor of the upper chamber slopes steeply to trapped slots through which solids may slide into the lower chamber. The lower chamber receives no fresh wastewater directly, but is provided with gas vents and with means for drawing digested sludge from near the bottom.

impermeable - Not allowing, or allowing only with great difficulty, the movement of water.

industrial wastes - The liquid wastes from industrial processes, as distinct from domestic or sanitary wastes.

infiltration - (1) The flow or movement of water through the interstices or pores of a soil or other porous medium. (2) The quantity of ground water that leaks into a pipe through joints, porous walls, or breaks.

influent - Water, wastewater, or other liquid flowing into a reservoir, basin, or treatment plant, or any unit thereof.

intercepting sewer - A sewer that receives dry-weather flow from a number of transverse sewers or outlets and frequently additional predetermined quantities of storm water (if from a combined system), and conducts such waters to a point for treatment or disposal.

intermittent stream - A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long-continued supply from melting snow or other sources.

ion-exchange treatment - The use of ion-exchange materials such as resin or zeolites to remove undesirable ions from a liquid and substitute acceptable ions.

irrigable land - Land under an existing or potential irrigation development which, because of topography, quality of land, and other characteristics, is physically suitable for sustained irrigation and for which an adequate and suitable water supply can be provided at reasonable cost.

irrigation - The artificial application of water to lands to meet the water needs of growing plants not met by rainfall.

lagoon - (1) A shallow body of water, as a pond or lake, which usually has a shallow, restricted inlet from the sea. (2) A pond containing raw or partially treated wastewater in which aerobic or anaerobic stabilization occurs.

land disposal - Disposal of wastewater onto land.

land use - Existing or zoned economic use of land, such as residential, industrial, farm, commercial.

leaching - (1) The removal of soluble constituents from soils or other material by percolating water. (2) The removal of salts and alkali from soils by abundant irrigation combined with drainage.

lift station - A small wastewater pumping station that lifts the wastewater to a higher elevation when the continuance of the sewer at reasonable slopes would involve excessive depths of trench, or that raises wastewater from areas too low to drain into available sewers. These stations may be equipped with pneumatic ejectors or centrifugal pumps.

lime - Any of a family of chemicals consisting essentially of calcium hydroxide made from limestone (calcite) which is composed almost wholly of calcium carbonate or a mixture of calcium and magnesium carbonate.

mean flow - The arithmetic average of the discharge at a given point or station on the line of flow for some specified period of time.

mechanical aeration - (1) The mixing, by mechanical means, of wastewater and activated sludge in the aeration tank of the activated sludge process to bring fresh surfaces of liquid into contact with the atmosphere. (2) The introduction of atmospheric oxygen into a liquid by the mechanical action of paddle, paddle wheel, spray, or turbine mechanisms.

milligrams per liter - A unit of the concentration of water or wastewater constituent. It is 0.001 g of the constituent in 1,000 ml of water. It has replaced the unit formerly used commonly, parts per million, to which it is approximately equivalent, in reporting the results of water and wastewater analysis.

minimum flow - The flow occurring in a stream during the driest period of the year. Also called low flow.

minimum grade - The grade of a sewer, not under pressure, sufficient to maintain the minimum velocity, when the sewer is partly full, that will prevent the deposition of material carried by the water.

most probable number (MPN) - That number of organisms per unit volume that, in accordance with statistical theory, would be more likely than any other number to yield the observed test result or that would yield the observed test result with the greatest frequency. Expressed as density of organisms per 100 ml. Results are computed from the number of positive findings of coliform-group organisms resulting from multiple-portion decimal-dilution plantings.

natural purification - Natural processes occurring in a stream or other body of water that result in the reduction of bacteria, satisfaction of the BOD, stabilization of organic constituents, replacement of depleted dissolved oxygen, and the return of the stream biota to normal. Also called self-purification.

neutralization - Reaction of acid or alkali with the opposite reagent until the concentrations of hydrogen and hydroxyl ions in the solution are approximately equal.

nitrification - The conversion of nitrogenous matter into nitrates by bacteria.

nitrobacteria - Bacteria that oxidize nitrite to nitrate.

nitrogen fixation - The utilization of free nitrogen in the formation of plant tissue in leguminous plants, bacterial protoplasm, or algae protoplasm by appropriate biological activity.

noncontributing area - In hydrology, that portion of a drainage area that, because of physical characteristics or topography, does not contribute surface runoff into a river system. In determination of drainage-basin yields, a noncontributing area is that which does not contribute either surface or ground water runoff.

normal- A mean or average value established from a series of observations, for purposes of comparison of some meteorological or hydrological event.

organic nitrogen - Nitrogen combined in organic molecules such as proteins, amines, and amino acids.

outfall - (1) The point, location, or structure where wastewater or drainage discharges from a sewer, drain, or other conduit. (2) The conduit leading to the ultimate disposal area.

outfall sewer - A sewer that receives wastewater from a collecting system or from a treatment plant and carries it to a point of final discharge.

overland runoff - Water flowing over the land surface before it reaches a definite stream channel or body of water.

oxidation - The addition of oxygen to a compound. More generally, any reaction which involves the loss of electrons from an atom.

oxidation lagoon - A type of oxidation pond.

oxidation pond - A basin used for retention of wastewater before final disposal, in which biological oxidation of organic material is effected by natural or artificially accelerated transfer of oxygen to the water from air.

oxidation process - Any method of wastewater treatment for the oxidation of the putrescible organic matter. The usual methods are biological filtration and the activated sludge process.

oxygen balance - (1) The dissolved-oxygen level at any point in a stream, resulting from the opposing forces of deoxygenation and reaeration. (2) The relation between the biochemical oxygen demand of a wastewater or treatment plant effluent and the oxygen available in the diluting water.

oxygen deficit - The difference between the dissolved oxygen level at saturation and the actual dissolved oxygen concentration in water.

oxygen demand - The quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions.

oxygen-sag curve - A curve that represents the profile of dissolved oxygen content along the course of a stream, resulting from deoxygenation associated with biochemical oxidation of organic matter and reoxygenation through the absorption of atmospheric oxygen and through biological photosynthesis. Also called dissolved-oxygen-sag curve.

oxygen saturation - The maximum quantity of dissolved oxygen that liquid of given chemical characteristics, in equilibrium with the atmosphere, can contain at a given temperature and pressure.

parts per million - The number of weight or volume units of a minor constituent present with each one million units of the major constituent of a solution or mixture. Formerly used to express the results of most water and wastewater analyses, but more recently replaced by the ratio milligrams per liter.

percolation - (1) The flow or trickling of a liquid downward through a contact or filtering medium. The liquid may or may not fill the pores of the medium. Also called filtration. (2) The movement or flow of water through the interstices or the pores of a soil or other porous medium.

permeability - The property of a material that permits appreciable movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water. Previousness is sometimes used in the same sense as permeability.

pH - The reciprocal of the logarithm of the hydrogen-ion concentration. The concentration is the weight of hydrogen ions, in grams, per liter of solution. Neutral water, for example, has a pH value of 7 and a hydrogen-ion concentration of 10^{-7}.

pollution - A condition created by the presence of harmful or objectionable material in water.

pond - A body of water of limited size, either naturally or artificially confined and usually smaller than a lake.

population equivalent - A means of expressing the strength of organic material in wastewater. Domestic wastewater consumes, on an average, 0.17 lb of oxygen per capita per day, as measured by the standard BOD test. This figure has been used to measure the strength of organic industrial waste in terms of an equivalent number of persons.

postchlorination - The application of chlorine to water or wastewater subsequent to any treatment, including prechlorination.

potable water - Water that does not contain objectional pollution, contamination, minerals, or infective agents and is considered satisfactory for domestic consumption.

preaeration - A preparatory treatment of wastewater consisting of aeration to remove gases, add oxygen, promote flotation of grease, and aid coagulation.

prechlorination - The application of chlorine to water or wastewater prior to any treatment.

preliminary treatment - (1) The conditioning of a waste at its source before discharge, to remove or to neutralize substances injurious to sewers and treatment processes or to effect a partial reduction in load on the treatment process. (2) In the treatment process, unit operations, such as screening and comminution, that prepare the liquor for subsequent major operations.

primary settling tank - The first settling tank for the removal of settleable solids through which wastewater is passed in a treatment works.

primary sludge - Sludge obtained from a primary settling tank.

primary treatment - (1) The first major treatment in a wastewater treatment works, usually sedimentation. (2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter.

probability curve - A curve that expresses the cumulative frequency of occurrence of a given event, based on an extended record of past occurrences. The curve is usually plotted on specially prepared coordinate paper, with ordinates representing magnitude equal to, or less than the event, and abscissas representing the probability, time, or other units of incidence.

raw sludge - Settled sludge promptly removed from sedimentation tanks before decomposition has much advanced. Frequently referred to as undigested sludge.

raw wastewater - Wastewater before it receives any treatment.

recarbonation - The diffusion of carbon dioxide gas through liquid to replace the carbon dioxide removed by the addition of lime.

recirculation - (1) In the wastewater field, the refiltration of all or a portion of the effluent in a trickling filter to maintain a uniform high rate through the filter. Return of a portion of the effluent to maintain minimum flow is sometimes called recycling. (2) The return of effluent to the incoming flow.

regenerated water - Water diverted from a stream or other body of water for irrigation purposes that, not having been consumed by evaporation or transpiration, passes directly back to a stream or other body of water or downward to the water table and ultimately reaches a surface stream or other body of water.

relief sewer - (1) A sewer built to carry the flows in excess of the capacity of an existing sewer. (2) A sewer intended to carry a portion of the flow from a district in which the existing sewers are of insufficient capacity, and thus prevent overtaxing the latter.

reservoir - A pond, lake, tank, basin, or other space, either natural or created in whole or in part by the building of engineering structures, which is used for storage, regulation, and control of water. Sometimes called impoundment.

residual chlorine - Chlorine remaining in water or wastewater at the end of a specified contact period as combined or free chlorine.

returned sludge - Settled activated sludge returned to mix with incoming raw or primary settled wastewater.

return flow - (1) Any flow of water that returns to a stream channel after diversion for irrigation or other purposes. (2) In irrigation, water that is not consumed in evapotranspiration and that returns to its source or another body of water.

runoff - (1) That portion of the earth's available water supply that is transmitted through natural surface channels. (2) In the general sense, that portion of the precipitation which is not absorbed by the deep strata, but finds its way into the streams after meeting the persistent demands of evapotranspiration, including interception and other losses. (3) That part of the precipitation which runs off the surface of a drainage area and reaches a stream or other body of water or a drain or sewer.

saline water - Water containing dissolved salts-usually from 10,000 to 33,000 mg/1.

salinity - The relative concentration of salts, usually sodium chloride, in a given water. It is usually expressed in terms of the number of parts per million of chlorine (Cl).

sanitary sewer - A sewer that carries liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with minor quantities of ground-, storm, and surface waters that are not admitted intentionally.

sanitary wastewater - (1) Domestic wastewater with storm and surface water excluded. (2) Wastewater discharging from the sanitary conveniences of dwellings, office buildings, industrial plants, or institutions.

scum - The layer or film of extraneous or foreign matter that rises to the surface of a liquid and is formed there.

secondary wastewater treatment - The treatment of wastewater by biological methods after primary treatment by sedimentation.

sedimentation - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called settling. See chemical precipitation.

sedimentation basin - A basin or tank in which water or wastewater containing settleable solids is retained to remove by gravity a part of the suspended matter. Also called sedimentation tank, settling basin, settling tank.

semiarid - Neither entirely arid nor strictly humid, but intermediate, with a tendency toward an arid character. May be applied to a dry farming country in which many crops grow without irrigation, but in which far better yields result from irrigation. The term semihumid has a similar significance with a tendency toward a humid character.

septic tank - A settling tank in which settled sludge is in immediate contact with the wastewater flowing through the tank and the organic solids are decomposed by anaerobic bacterial action.

settling - The process of subsidence and deposition of suspended matter carried by water, wastewater, or other liquids, by gravity. It is usually accomplished by reducing the velocity of the liquid below the point at which it can transport the suspended material. Also called sedimentation.

sewage - The spent water of a community. Term now being replaced in technical usage by preferable term wastewater.

__sewer__ - A pipe or conduit that carries wastewater or drainage water.

__sewerage__ - System of piping, with appurtenances, for collecting and conveying wastewater from source to discharge. Term declining in use.

__sewer system__ - Collectively, all of the property involved in the operation of a sewer utility. It includes land, wastewater lines and appurtenances, pumping stations, treatment works, and general property. Occasionally referred to as a sewerage system.

__sloughing__ - The disattachment of slime and solids accumulated on the media of trickling filters and contact areas. Sloughed material usually appears in the effluent.

__sludge__ - (1) The accumulated solids separated from liquids, such as water or wastewater, during processing, or deposits on bottoms of streams or other bodies of water. (2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

__sludge bed__ - An area comprising natural or artificial layers of porous material on which digested wastewater sludge is dried by drainage and evaporation. A sludge bed may be open to the atmosphere or covered, usually with a greenhouse-type superstructure. Also called sludge drying bed.

__sludge digestion__ - The process by which organic or volatile matter in sludge is gasified, liquified, mineralized, or converted into more stable organic matter through the activities of either anaerobic or aerobic organisms.

__sludge thickener__ - A tank or other equipment designed to concentrate wastewater sludges.

__spray irrigation__ - A method for disposing of some organic wastewaters by spraying them on land, usually from pipes equipped with spray nozzles. This has proved to be an effective way to dispose of wastes from the canning, meat-packing, and sulfite-pulp industries where suitable land is available.

__spring__ - A surface where, without the agency of man, water issues from a rock or soil onto the land or into a body of water, the place of issuance being relatively restricted in size. Springs are classified in accordance with many criteria, including character of water, geologic formation, geographical location, etc.

__sprinkler irrigation__ - Irrigation by means of sprinklers spaced at intervals on a pipe so the areas of influence cover the areas to be irrigated. Pressure for the sprinklers is usually furnished by pumps.

__stabilization pond__ - A type of oxidation pond in which biological oxidation of organic matter is effected by natural or artificially accelerated transfer of oxygen to the water from air.

__storm sewer__ - A sewer that carries storm water and surface water, street wash and other wash waters, or drainage, but excludes domestic wastewater and industrial wastes. Also called storm drain.

__stream__ - (1) A course of running water usually flowing in a particular direction in a definite channel and discharging into some other stream or body of water. (2) In the law of water rights, the distinction between stream and water which appears on the surface in a diffused state with no permanent source of supply or regular course for any considerable time is important. Surface water may at times collect and flow through a land depression or gully, but a stream usually flows, even though it may be dry temporarily.

__suspended solids__ - (1) Solids that either float on the surface of, or are in suspension in, water, wastewater, or other liquids, and which are largely removable by laboratory filtering. (2) The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

__tile drainage__ - The removal of surplus ground water by means of buried pipes. Water enters through the unsealed joints or through perforations in the pipe. Water sometimes enters the drain tile through surface inlets.

total solids - The sum of dissolved and undissolved constituents in water or wastewater, usually stated in milligrams per liter.

transpiration - The process by which water vapor is lost to the atmosphere from living plants.

trickling filter - A filter consisting of an artificial bed of coarse material, such as broken stone, clinkers, slate, slats, brush, or plastic materials, over which wastewater is distributed or applied in drops, films, or spray from troughs, drippers, moving distributors, or fixed nozzles, and through which it trickles to the underdrains, giving opportunity for the formation of zoogleal slimes which clarify and oxidize the wastewater.

trunk sewer - A sewer that receives many tributary branches and serves a large territory.

turbidity- (1) A condition in water or wastewater caused by the presence of suspended matter, resulting in the scattering and absorption of light rays. (2) An analytical quantity usually reported in arbitrary turbidity units determined by measurement of light diffraction.

waste treatment - Any process to which wastewater or industrial waste is subjected to make it suitable for subsequent use.

wastewater - The spent water of a community. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions, together with any ground water, surface water, and storm water that may be present. In recent years, the word wastewater has taken precedence over the word sewage.

wastewater lagoon - An impoundment into which wastewater is discharged at a rate low enough to permit oxidation to occur without substantial nuisance.

water district - An organization, created and operating under statutory enactment, for the purpose of financing, construction, and operating a water supply system.

watershed - The area contained within a divide above a specified point on a stream. In water supply engineering, it is called a watershed or a catchment area; in river control engineering, it is called a drainage area, a drainage basin, or a catchment area.

well - An artificial excavation that derives water from the interstices of the rocks or soil which it penetrates.

VII. WATER USAGE PARAMETERS

Introduction

The desire to reclaim and reuse wastewater is becoming a major concern due to the growing shortage of surface waters. Technology is available and continuously being refined to produce usable quality water from wastewater. Evaluation of the possibility of reusing treated wastewater requires a knowledge of the quality of water needed in the area under study. This section establishes the base from which to evaluate water uses and quality requirements on an area-wide scale.

Water usage and the corresponding quality desired were evaluated, utilizing the "Report of the National Technical Advisory Committee on Water Quality Criteria," Department of the Interior, and The California State Water Resources Control Board's "Water Quality Criteria." These publications include the parameters covered by the Public Health Service, "Drinking Water Standards."

Water usage requirements were determined utilizing agricultural and livestock, raw domestic water, and industrial process water quality parameters. The industrial process water quality is dependent upon the type of industry. The general industrial classifications of the "Texas Manufacturers 1971", Bureau of Business Research, the University of Texas at Austin were used to determine types of industry in the counties in the Colorado River Basin study area.

Presentation of Data

The water usage requirements for all regions of the Colorado River Basin are the same for domestic raw water and agricultural farmstead and livestock needs. The parameters governing these usages are presented in tabular form.

The industrial process water requirements are presented in tabular form by major industrial groups.

TABLE VII-1

STANDARDS FOR DOMESTIC RAW WATER SOURCES

Parameter	(1) State of California	(2) Department of the Interior
BOD mg/l	1.5 - 2.5	-
Total Coliform MPN/100 ml	50 - 50,000	10,000
Dissolved Oxygen mg/l	4.0 - 6.5	$\geq$ 4.0
pH	5.0 - 9.0	6.0 - 8.5
Chlorides mg/l	50 - 250	250
Fluorides mg/l	1.5 - 3.0	0.8 - 1.2
Phenolic Compounds mg/l	0.005	0.001
Color	20 - 150	75
Turbidity JTU	10 - 250	not defined
Temperature $^{\circ}$F	-	$\leq$ 85
Total Dissolved Solids mg/l	-	500

(1) State of California parameters are for "Good Source."

(2) Dept. of the Interior parameters are "Permissible Levels."

TABLE VII-2

STANDARDS FOR FARMSTEAD WATER SOURCES

Parameter	State of California	Department of the Interior
Taste and Odor	-	Substantially free
pH	-	6.0 - 8.5
Total Dissolved Solids mg/l	350 - 2100 (1)	500 - 1000 (1)
Chlorinated Organic Pesticides (DDT)		42 microgram/l
Arsenic mg/l		0.05
Barium mg/l		1.00
Cadmium mg/l		0.01
Chromium mg/l		0.05
Lead mg/l		0.05
Cyanide mg/l		0.20
Silver mg/l		0.05
Manganese mg/l		0.05
Iron mg/l		0.30
Copper mg/l		0.10
Fluoride mg/l		0.7 - 1.2
Nitrate mg/l		45
Chlorides mg/l	70 - 250	35 - 200
Sulfates mg/l	170 - 480	-
Sodium Adsorption Ratio(S. A. R.)	<10	4 to 8

(1) Dependent upon crop sensitivity

TABLE VII-3

STANDARDS FOR LIVESTOCK WATER SOURCES

Parameter	State of * California	Department of* the Interior
Total Dissolved Solids mg/l	1000 - 4000	< 10,000(1)
Bacterial	Treated Water	Not specific
Fluoride mg/l	1.0	< 2.4
Nitrate mg/l	<114	-
Chlorides mg/l	-	1500
Sulfates mg/l	1000	1000
Lead mg/l	0.5	0.5
Arsenic mg/l	1.0	0.05
Chromium mg/l	5.0	0.05
Selenium mg/l	0.4 - 0.5	< 0.01

***Based on following quantities of consumption:**

	gallons/day/head
Beef Cattle	7 - 12
Dairy Cattle	10 - 16
Horse	8 - 12
Swine	3 - 5
Sheep-Goats	1 - 4

(1) Dependent on animal species.

TABLE VII - 4

INDUSTRIAL WATER QUALITY
REQUIREMENTS FOR FOOD AND KINDRED PRODUCTS

Parameter	State of California	Department of the Interior
Turbidity JTU	1 - 10	"drinking water"
Color	5 - 10	5
Taste & Odor	low barely noticeable	"not detectable"
Fe mg/l	0.2	0.2
Mn mg/l	0.2	0.2
Fe & Mn mg/l	0.2 - 0.3	-
Alkalinity ($CaCO_3$) mg/l	30 - 250	250
Hardness ($CaCO_3$) mg/l	10 - 250	250
Total Dissolved Solids mg/l	850	500
Fluoride mg/l	1.0	1.0
NO_3 mg/l	-	10
pH	-	6.5 – 8.5

TABLE VII-5

INDUSTRIAL WATER QUALITY
REQUIREMENTS FOR TEXTILE MILL PRODUCTS

Parameter	State of California	Department of the Interior
Turbidity	0.3 - 25	5
Color	0 - 70	0.3
Fe mg/l	0.1 - 1.0	0.05
Mn mg/l	0.05 - 1.0	
Fe & Mn mg/l	0.2 - 1.0	
Hardness ($CaCO_3$) mg/l	0 - 50	25
Chemical Oxygen Demand mg/l	8	
Ca mg/l	10	
Mg mg/l	5	
SO_3 mg/l	100	
Chlorides mg/l	100	
Bicarbonate ($CaCO_3$) mg/l	200	
Cu mg/l		0.05
Dissolved solids mg/l		100
Suspended solids mg/l		5
pH		6.0 - 10.5

TABLE VII -6

INDUSTRIAL WATER QUALITY
REQUIREMENTS FOR PAPER AND ALLIED PRODUCTS

Parameter	State of California	Department of the Interior
Turbidity	10 - 100	
Color	5 - 100	5
Hardness ($CaCO_3$) mg/l	100 - 200	2
Alkalinity ($CaCO_3$) mg/l	75 - 150	
Fe mg/l	0.1 - 1.0	0.1 - 0.3
Mn mg/l	0.05 - 0.5	0.01 - 0.05
Total Dissolved Solids mg/l	20 - 100	100
Chloride mg/l	10	
pH		2.5 - 10.5

TABLE VII-7

INDUSTRIAL WATER QUALITY
REQUIREMENTS FOR CHEMICAL AND ALLIED PRODUCTS

Parameter	State of California	Department of the Interior
Silica (SiO_2) mg/l	not specific	50
Fe mg/l	"	0.1 - 0.3
Mn mg/l	"	0.1 - 0.2
Ca mg/l	"	68 - 100
Mg mg/l	"	19 - 50
HCO_3 mg/l	"	128 - 250
SO_4 mg/l	"	100
Total dissolved solids mg/l	"	
Hardness ($CaCO_3$) mg/l	"	250 - 900
Alkalinity ($CaCO_3$) mg/l	"	125 - 200
pH	"	6.5 - 8.7
Color	"	20
Chloride mg/l	"	500

TABLE VII - 8

INDUSTRIAL WATER QUALITY REQUIREMENTS
FOR PETROLEUM REFINING AND RELATED PROCESSES

Parameter	State of California	Department of the Interior
Fe mg/l	not specific	1.0
Ca mg/l	"	75
Mg mg/l	"	30
Chloride mg/l	"	300
Total dissolved solids mg/l	"	1000
Suspended solids mg/l	"	10
Hardness mg/l	"	350
pH	"	6.0 - 9.0

TABLE VII - 9

INDUSTRIAL WATER QUALITY REQUIREMENTS FOR LEATHER AND LEATHER GOODS INCLUDING TANNING

Parameter	State of California	Department of the Interior
Turbidity	20	-
Color	10 - 100	5
Hardness ($CaCO_3$) mg/l	50 - 513	150
Alkalinity ($CaCO_3$) mg/l	128 - 135	-
pH	6.0 - 8.0	6.0 - 8.0
Fe & Mn mg/l	0.2	-
Fe mg/l	0.1 - 0.2	0.1 - 50
Mn mg/l	0.1 - 0.2	0.01 - 0.2
Ca mg/l		60
Chloride mg/l		250
SO_4 mg/l		250

TABLE VII-10

INDUSTRIAL WATER QUALITY
REQUIREMENTS FOR THE PRIMARY METALS INDUSTRY

Parameter	State of California	Department of the Interior
Temp ^{o}F	75	100
Chlorides mg/l	175	-
pH	6.8 - 7.0	5 - 9
Hardness mg/l	50	100
Suspended Solids mg/l	25	10